Masters Thesis in Engineering

Preference Analysis on Zero Energy Apartment in Housing Choice Situation

- In Case of Korea -

주거선택상황에서 제로에너지아파트에 대한 선호분석
: 한국을 중심으로

August & 2019

Graduate School of Seoul National University

Technology Management, Economics, and Policy Program

Dohyeong Kee

Preference Analysis on Zero Energy Apartment in Housing Choice Situation

-In Case of Korea-

지도교수 이종수

이 논문을 공학석사학위 논문으로 제출함

2019 년 08 월

서울대학교 대학원

협동과정 기술경영경제정책 전공

기도형

기도형의 공학석사학위 논문을 인준함

2019 년 8 월

위 원 장 구 윤 모 (인)

부위원장 이 종 수 (인)

위 원 안 중 하 (인)

Abstract

Preference Analysis on Zero Energy Apartment in Housing Choice Situation

Dohyeong Kee
Technology Management, Economics, and Policy Program
The Graduate School
Seoul National University

Global efforts are being carried out to alleviate climate change by reducing energy demand and Greenhouse Gas emission such as CO_2. Korean government announced New Energy Industry, which is a set of business models of core policies related to achieving CO_2 emission and energy demand reduction, that can potentially revitalize Korean economy. Zero Energy Building is one of the business models of New Energy Industry, which has high energy efficiency and renewable energy facility. Unlike the government's expectation, the diffusion of Zero Energy Buildings is very slow. This study tries to deal with apartment's Zero Energization, which does not seem to be supplied in the market. Consumers' preference studies on Zero Energy Apartments have not been carried out in case of Korea, meaning that construction firms that need to supply apartments will lack the basis to make decisions on the supply of Zero Energy Apartments with unclear demand. In this study, stated preference data was obtained from 701 respondents through survey and the data was analyzed using the mixed logit model. As a result, respondents were found to have high preference on Zero Energy Apartment and eco-friendly attributes. From the result of this study, it was possible to confirm the feasibility of government's plan of Zero Energization obligation on private buildings in 2025 and to provide the basis for supplying Zero Energy Apartments to construction firms.

Keywords: Zero Energy Building, Conjoint Survey, Mixed Logit Model, Consumer Preference, Discrete Choice Experiment
Student Number: 2017-20128

Contents

List of Tables

List of Figures

Chapter 1. Introduction

Global warming is an overlapping issue around the world. Our earth is getting warmer saturated with Greenhouse Gas by the result of excessive exhaustion. As a result of excessive Greenhouse Gas emission, the average surface temperature is increasing rapidly. According to United Nations Environment Programme, forecasted amount of global emission of Greenhouse Gas is expected to reach 59GigatonCO_2 by 2020, and 87GigatonCO_2 by 2050. Trenberth et al. (2007) posited that average surface temperature of earth increased about 0.74±0.18 degrees Celsius from 1906 to 2005. Table 1 shows forecasted amount of business as usual global Greenhouse Gas emission.

Table 1. Forecasted Business as Usual Global Greenhouse Gas Emission

Year	Amount of emission
2020	59 GigatonCO_2
2025	61 GigatonCO_2
2030	65 GigatonCO_2
2050	87 GigatonCO_2

<The Emissions Gap Report, 2014>

Forecasted acceleration of high level of Greenhouse Gas emission has drawn people's concern globally to protect the planet's environment and therefore, global efforts are being carried out to alleviate the acceleration of Greenhouse Gas emission. At 2015 United Nations Climate Change Conference, Conference of the Parties held in Paris, France, Paris Agreement was negotiated to promote reduction of climate change. Most of the parties including Korea have arranged and submitted Greenhouse Gas emission reduction plans, as well as energy efficiency improvement plans, to United Nations. Approximately 200 countries, occupying more than 87% of the global carbon emission, are implementing the plans as agreed in Paris Agreement[1].

Korea is one of the highest Greenhouse Gas emitting countries. Korea emitted 69MegatonCO_2 in 2016 and was world's 12th and OECD's 6th highest Greenhouse Gas emitting country (Ministry of Environment, 2018). Since Korea holds a large proportion in global Greenhouse Gas emission, the Korean government have managed to arrange drastic plans to show confidence toward reduction of climate change. The country's goal is to reduce Greenhouse Gas emission by 37% of business as usual by year 2030 (Lee & Park, 2017). Apart from accompanying in global reduction efforts, the Korean government announced '2030 New Energy

---

[1] Paris Agreement replaces the Kyoto Protocol adopted in 1997 with a new climate agreement to be applied after year 2020. Under the Kyoto Protocol, only advanced countries were obliged to reduce Greenhouse Gas emissions, but all the 195 parties in the Paris Agreement must participate (Annalisa Savaresi, 2016).

Industry Expansion Strategies' to actively respond to fluctuating global energy market paradigm. New Energy Industry is a set of business models of core policies that can be utilized as new economic growth power and revitalization related to energy demand control and Greenhouse Gas reduction. The New Energy Industry is consisted of 8 business models including Electronic Vehicles, Energy Storage System, Zero Energy Buildings, Solar Panel Rental System, and etc. (Choi, 2016).

Choi (2015) posited that energy use has been increasing rapidly in buildings, and Choi (2016) noted that building's energy demand is considerably high, taking over more than 19% of the total energy use in Korea. Additionally, out of the total energy demand of buildings, residential buildings hold the largest proportion. According to Global Green Growth Institute (2015), as of 2010, residential buildings hold more than 53% of the total energy use in buildings. Residential building's energy demand is known to be caused by heating, cooling, lighting and ventilation, while heating takes the largest proportion in the residential building's energy demand.

Since Buildings hold large proportion in total energy demand of Korea, and the residential buildings hold the largest share in total energy use of buildings, reduction of energy use in residential buildings can be an efficient way to reduce Greenhouse Gas emission as well as energy demand. This paper concentrates on analyzing consumers' preference on Zero Energy Apartment, one of the New

Energy Industry business models that Korean government have announced. Out of several types of residential buildings, apartment was chosen in this study because apartment is the most common type of residence in Korea, holding the largest share in the types of residential buildings, where more than 50% of the total Korean residents live, and the proportion is steadily increasing.

First, to comprehend why this paper focuses on Zero Energy Apartment, understanding basic concept of Zero Energy Building is necessary. Zero Energy Building is a type of building that has great energy efficiency, which can fulfill its energy demand by installing renewable energy generating facility (P. Torcellini, S. Pless, and Deru, 2006). High energy efficiency can be achieved by using high performance insulation product and ventilation system in the design and construction process, making it possible for the building to maintain its temperature without being easily affected by outdoor temperature. Since indoor temperature fluctuation can be protected, there are less energy demand for heating or cooling indoor air temperature. Figure 1 simply introduces how Zero Energy Building is operated. Conceptual Zero Energy Building is possible when the energy produced from the generating facility exceeds the building's energy demand. However, Zero Energy Building with perfect energy independence is not likely to be built due to technological and capital constraints. However, many countries including Korea introduced Nearly Zero Energy Building concept that ease the original concept. Nearly Zero Energy Building can be understood as almost Zero Energy Building. It cannot perfectly eliminate the use of energy generated by fossil fuel to zero level, but it can reduce the use of energy to a certain level depending on the energy efficiency and power generator's performance of the building.

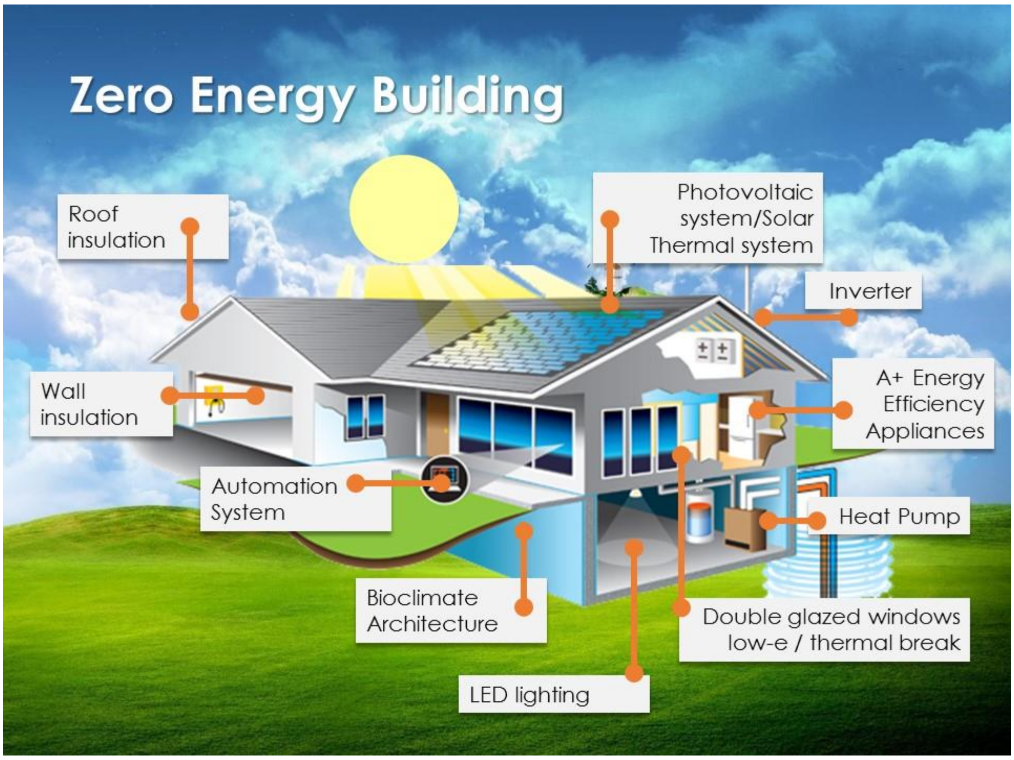

Figure 1. Concept How Zero Energy Building is Feasible (Zero Energy Building Project Report, 2018)

Korea, using the Nearly Zero Energy Building concept, is implementing Zero Energy Building Certification System and any type of building including government buildings, residential buildings or commercial buildings can be certified. Korea's certification system has certain energy independence baselines to be certified as Zero Energy Building. Specific information on Korea's Zero Energy Building Certification System will be introduced in Literature Review section.

Apart from Greenhouse Gas emission, Zero Energy Building can be the solution to resolve energy security problems, since Korea's energy generating resources are insufficient compared to the amount of energy demand (U.S. Energy Information Administration, 2014). Also, as announced by the government, Zero Energy Building can revitalize the Korean economy.

Several advantages are expected by Zero Energy Building. Diffusion of Zero Energy Building will bring energy efficiency maximization in domestic buildings and eventually reduce the total amount of energy use and Greenhouse Gas emission. However, Zero Energy Building diffusion plan, which is expected to be successfully implemented in Korea, should be considered in consumer's perspective, since consumers' choices are unexpectable. Consumers are very sensitive to price and might not prefer Zero Energy Building when the price exceeds consumers' willingness to pay even though it holds many advantages. In other words, checking that consumer's choice will be as Korean government expects is necessary. To establish successful diffusion strategy for Zero Energy Building, and maximized energy efficiency, it is important to investigate consumers' level of acceptance. However, consumers' preference toward Zero Energy Building or Zero Energy Apartment has not been researched in case of

Korea. Therefore, this paper aims to analyze consumers' preferences on Zero Energy Apartment using housing choice situation to suggest successful strategies for efficient diffusion of Zero Energy Apartments.

In Chapter 2, literature reviews including policies of Korea and foreign countries will be introduced. In Chapter 3, methodology and empirical model to analyze consumers' choice will be introduced. In Chapter 4, result of empirical analysis will be shown. Finally, in Chapter 5, contents of this study will be looked over briefly and implications of this research will be suggested.

Chapter 2. Literature Review

This study aims to analyze consumers' housing choice with the attributes of Zero Energy Apartment. Before reviewing existing studies to establish attributes of Zero Energy Apartment, recent status of Korea's Zero Energy Building policies and international Zero Energy Building related policies will be introduced.

2.1 Korean Zero Energy Building Certification System and Status

Korea's Zero Energy Building Certification System was implemented in January 20th, 2017, followed by the revision of Green Building Construction Support Act in January 19th, 2016 ("Implementation of Zero Energy Building Certification System", n.d.). Green Building Construction Act defines Green Building Certification System, Building Energy Efficiency Rating System, and Zero Energy Building Certification System (Kim, 2017). Certification systems enforced under the Green Building Act is listed in Table 2.

Zero Energy Building Certification System is an advanced concept compared to Green Building Certification and Building Energy Efficiency System in that it can promote not only the reduction of environmental destruction with excessive energy use but also promotes the use of renewable energy facilities to achieve energy independence. Zero Energy Building Certification System certifies buildings that satisfy energy efficiency grade over 1++ and energy independence over 20% with Building Energy Management System. Building Energy Efficiency System rating over 1++ is shown in Table 3.

Table 2. Certification Systems Enforced Under Green Building Act

	Green Building	Building Energy Efficiency Rating	Zero Energy Building
Purpose	- Activation of resource saving and environment friendly buildings	- Demand expansion of high energy efficiency buildings - Efficient management of building's energy efficiency	- Expansion of buildings with high energy efficiency
Operating Ministry	Operated by - Ministry of Land, Infrastructure and Transport - Ministry of Environment	Operated by - Ministry of Trade, Industry and Energy - Ministry of Land, Infrastructure and Transport	Operated by - Ministry of Land, Infrastructure and Transport
Certification Target	Every type of building is capable of being certified (Mandatory: Public institution building over 3,000m^2 in size)	Every type of building is capable of being certified (Mandatory: Every building ordered by public institution)	Buildings applied by the owner with building energy efficiency rating over 1++

<Current Status of Zero Energy Buildings and Improvement Tasks, Kim, 2017>

Korea is operating Zero Energy Building Certification System with 5 grades.

The ratings are sorted by the building's energy independence. Energy independence is calculated by dividing the total energy produced by the building by the total energy demand of the building ("Activation of Zero Energy Building", n.d.). Grade criteria of Zero Energy Building Certification System is listed in Table 4.

Table 3. Building Energy Efficiency Rating Criteria Over 1++

Rating	House Buildings	Buildings except House Buildings
	Primary Energy Demand (kWh/m^2, year)	Primary Energy Demand(kWh/m^2, year)
1+++	Below	Below 80
1++	Over 60, Below 90	Over 80, Below 140

<Outline of building energy efficiency rating, Korea Research Institute of Eco-Environmental Architecture>

Zero Energy Building Certification System give variety of incentives to the buildings that are certified. The incentives are given to promote the diffusion of Zero Energy Buildings. For example, it alleviates building standard such as floor area ratio by more than 10% according to the Zero Energy grade of the building. It also grants subsidy to install renewable energy generating facility from 30-50% of the total construction cost according to the grade level. Specific incentives of the Zero Energy Building Certification System are listed in Table 5.

Table 4. Zero Energy Building Certification System

Zero Energy Grade	Energy Independence
1	Energy Independence and above 100%
2	Energy Independence and above 80%, Energy Independence under 100%
3	Energy Independence and above 60%, Energy Independence under 80%
4	Energy Independence and above 40%, Energy Independence under 60%
5	Energy Independence and above 20%, Energy Independence under 40%

<Ministry of Land, Infrastructure, and Transport >

Table 5. Zero Energy Building Certification System

Incentives	Content	Note
Alleviation of building standards	- alleviates building standards(height, floor area ratio) according to the grade	
Subsidy	- subsidy granted when installing renewable energy generator from 30% to 50%. (according to the price announced by the Ministry of Trade, Industry and Energy)	- subsidized after completion
Loan limit Extension	- mitigates loan limit to the house or buildings by 20% .	

Mitigation of donation for infrastructure	- Up to 15% reduction rated applied to infrastructure contribution burden level
Monitoring support	- Support in check energy efficiency or energy demand through Building Energy Management System - Provide improvement measures on energy efficiency
Tax benefits	- acquisition tax reduction up to 15% - Income tax or corporate tax deduction for partial investment costs of energy saving facilities such as renewable energy generators and Building Energy Management System.

<Ministry of Land, Infrastructure and Transport, Incentives>

Korean government is putting effort to derive early and efficient diffusion and activation of Zero Energy Buildings including government buildings, public institution buildings and private buildings until 2025 by establishing step-by-step roadmaps. Korean government's plan was to make certification of market type public corporation buildings mandatory by 2017, quasi-market type public corporation buildings by 2018, and every public building by 2020. After all the public and government related buildings are certified as Zero Energy Buildings, all the private buildings will be mandatory to be certified as Zero Energy Buildings, making all the newly constructed buildings in Korea to become Zero Energy Buildings ("Zero Energy Building Roadmaps", n.d.).

Figure 2. Korean Government's Zero Energy Building Roadmap

According to Korea Energy Agency, as of July 2018, there are 21 buildings that are certified as Zero Energy Buildings. 5 are residential buildings and the rest are non-residential buildings. Status of certified buildings as of July 2018 is shown in Table 6.

Table 6. Zero Energy Certified Buildings in Korea as of July 2018

	Residential Buildings	Non-Residential Buildings	Total
Number of Buildings Certified	5	16	21
Average Zero Energy Grade Granted	Grade 5	Grade 5	Grade 5
Average Energy Independence	Approximately 34.86%	Approximately 42.64%	Approximately 40.79%

<Korea Energy Agency, Certified Building List>

Certified buildings have 41% energy independence on average and their average grade is 5, which is the lowest grade achievable in the certification system. The main reason most of the certified buildings have grade of 5 is because achieving high energy independence is very costly and technologically difficult in the designing and construction process. Many construction firms in Korea have announced that construction expenses of the Zero Energy Building are extremely high and risky compared to those of constructing existing buildings with experience. From Table 6, it is clear that Zero Energy certification of residential buildings are not being carried out since number of samples of the residential buildings are small compared to that of non-residential buildings. It is also because different from non-residential buildings mostly consisted of public institution buildings, residential buildings are purchased by consumers and consumers' willingness to buy Zero Energy Buildings have not been researched or analyzed.

2.2 International Zero Energy related Policies and System

International Zero Energy related policies will be introduced briefly in this section. Most of the developed countries are putting effort to diffuse Zero Energy Building. As explained in Introduction, making every building with perfect energy independence is not feasible. Therefore, Nearly Zero Energy Building concept is widely used. Definition on Zero Energy Building is slightly different among countries since each of them has different technological and economical status.

European Union has been implementing policies where all the member countries are required to certify energy consumption of commercial and residential buildings through Energy Performance of Building Directive since 2002 and all European Union members have been required to mark energy efficiency grade for all the newly constructed buildings since 2009 including existing buildings. In addition, most of the member countries set their goals to achieve Zero Energization on all the newly constructed buildings by 2020 through Energy Performance of Building Directive in 2010.

In case of United States of America, Japan, and England, they considered activation of Zero Energy Building in an economically feasible way and introduced Zero Energy Ready Building, which is not a Zero Energy Building, but has the potential to switch to a Zero Energy Building with additional facilities such as renewable energy generators. Zero Energization goals of the countries are briefly introduced in Table 7.

Table 7. Zero Energy Goals of Foreign Countries

Country	Content
France	- by 2012, mandatory for all the newly built buildings to become low energy

	building (under 50kWh/m^2·yr) - by 2020, mandatory for all the newly built buildings to become Plus Energy Building (BEPOS)
Germany	-by 2012, reduction of energy demand of the buildings by 30% compared to 2009 (About 50kWh/m^2·yr) - by 2020, goal to build climate neutral buildings with zero fossil fuel use
Sweden	- by 2011, reduction of energy demand of the buildings by 25% compared to 2008 - by 2015, 25% of the newly built buildings to be Nearly Zero Energy Building - by 2021, every buildings to become Nearly Zero Energy Buildings
England	-by 2010, reduction of energy demand of the buildings by 25% compared to 2006 - by 2013, 44% compared to 2006 - by 2019, all the buildings to become Zero Carbon (39-46kWh/m^2·yr depending on building type)
USA	- by 2020, general house buildings to become Nearly Zero Energy Buildings - by 2030, public and commercial buildings to become Nearly Zero Energy Buildings
Japan	- by 2020, Every newly built public building to become Nearly Zero Energy Buildings - by 2030, every newly built building to become Nearly Zero Energy Buildings

< Korea Institute of Civil Engineering and Building Technology, 2017>

2.3 Review of existing studies

The goal of this study is to analyze consumers’ preference on Zero Energy Apartment in housing choice situation through Discrete Choice Experiment.

Discrete Choice Experiment is an experiment that can identify consumers' preferences by suggesting hypothetical alternative that can actually exist in the market. In the survey, respondents are asked to select the most preferred alternative. Questionnaire used in the Discrete Choice Experiment is designed based on the attributes and its levels. In their housing choice situations, respondents take variety of attributes into account, and there are differences in the relative importance of the attributes that each consumer considers.

Before reviewing existing studies to set attributes for Zero Energy Apartment, this study considered the characteristics of the Zero Energy Apartment. First, Zero Energy Apartment is essentially bought for residential purpose. Second, it is an environment friendly building that can reduce CO_2 emission and energy demand. Third, it is an apartment with renewable energy generating facility. The attributes of Zero Energy Apartment were set based on the three characteristics.

Zero Energy Apartment is essentially an apartment. General attributes used in general housing choice models were reviewed. Almost uncountable attributes such as price of the house, size of the house, number of bedrooms, distance from amenities, quality of the schools nearby, degree of securities, and etc. were used in the housing choice studies, meaning that each attributes can affect or restrict the consumers' housing choice according to the purpose of individuals' residence. Existing studies of housing choice with variety of attributes will be introduced (Yong Tu & Goldfinch. 1996; Louviere, J., & Timmermans, H. 1990; Molin, Oppewal & Timmermans. 1996, Kim et al. 2005; DA Macpherson & G, S. S., 1999; M.Gluszak, 2015).

Louviere, J., & Timmermans, H. (1990) studied consumers' housing choices using hierarchical model. Louviere, J., & Timmermans, H. (1990) considered variety of attributes. Attributes used in the study were house related attributes, residential environment related attributes, relative location related attributes, and social and economic ties related attributes. For the house attributes, number of bedrooms, size of backyard, type of house was considered. Residential environment attributes were consisted of distance to parking lot, traffic noise, privacy level, surrounding environment. Relative location attributes considered distance to school, distance to stations, distance to shopping center, and commute distance. Social and economic ties attributes were presence of family, friends and workplace near the house. With the four main attributes Louviere, J., & Timmermans, H. (1990) tried to analyze consumers' preference. The result was that consumers consider house attributes followed by residential environment, social and economic ties, and relative location.

Molin et al. (1996) studied how to measure preference in consumers' housing choice situation. Considered attributes were size of living room, price of house, number of bedrooms, size of backyard, distance to parking lot, height of the neighbor's building, surrounding environment, distance to shopping center, and whether the house was for own or rent. Consumers thought price as the most important attribute when choosing their house, and size of living room was the second most important attribute.

Kim et al. (2005) wanted to study attributes affecting consumers' housing choice and willingness to move in Oxford, England. Chosen attributes in this study were characteristics of household, type of the housing, traffic convenience, and surrounding environment. Traffic convenience was most considered for consumers to decide to move to new place, and after deciding to move, traffic and environment was mostly considered.

Yong Tu and Goldfinch (1996) suggested that consumers' housing choices are decided by components of the house, individual's budget constraint, and supply constraint of house. In Yong Tu and Goldfinch (1996), local attributes such as presence of amenities, quality of the school, marketability and house attributes such as size of the house, appearance of the house, age of the house was considered as core attributes that affects consumers' housing choice. The study insisted that local attributes combined with house attributes drew consumers' heterogenetic demand. Multinomial Logit Model was used to analyze revealed preference data and found that consumers prefer houses that are located in place with high marketability, low distance to workplace and good schools.

Essential attributes of residence such as location, marketability, distance to amenities, and environments have been widely used in existing studies. Apart from considering essential attributes, many studies also focused on the attributes related to environment. While number of studies that used environment friendly attributes are relatively smaller compared to preference studies for attributes related to the housing choice, the interest of researchers and consumers is growing as environmental degradation, global warming and worsening air quality are accelerating globally. Studies considering the eco-friendly attributes of residential buildings mostly have been conducted based on stated preference data from surveys as it is difficult to obtain current market data such as actual market transaction details (Banfi et al. 2008; Kwak, Yoo, and Kwak. 2010; Hu, Geertman, and Hooimeijer. 2014; Park et al. 2009; Lee et al. 2012).

Banfi et al. (2008) investigated acceptance on eco-friendly attributes of residential building by analyzing consumers' willingness to pay about energy saving measures of residential buildings in Switzerland. The attributes used as eco-friendly measures were type and thickness of the windows, thickness of the insulation product related to insulation performance of the building, presence and improvement of ventilation, and price increase of the residence. The study considered the three attributes as energy saving measures of residential buildings and analyzed them by using stated preference data from survey with Standard Logit Model. People in Switzerland were found to be willing to pay an additional 3 percent of the sale or rental price of their residential buildings for improved insulation, and 4-12% more for installing ventilation systems if they were to move to a new house. For the residential buildings where the respondents presently live in, they were willing to pay an additional 6% and 13% of the price for improved insulation and insulated windows, respectively. By deriving Swiss' marginal willingness to pay, the government was able to roughly present subsidies required to promote energy efficient residential buildings to consumers, and it also suggested the necessity of companies that they should play an auxiliary role, such as lowering the interest on loans to consumers who want energy efficient houses.

Study was carried out in Korea with the methodology used in Banfi et al. (2008). Kwak et al. (2010) applied the idea to Korean consumers. In case of Korean consumers, it was found that they were willing to pay 1,112 KRW for 1mm thicker insulation, and 11,827 KRW for installing ventilation system. From Kwak et al. (2010) it is clear that Korean consumers have certain amount of preference and demand on energy efficient residential buildings.

In Park et al. (2009) consumers' marginal willingness to pay of Korean and Japanese about lighting and heating expenditure reduction, CO_2 deduction, reduction of hazardous chemical emission and automation of house was analyzed and compared. Consumers in Korea and Japan did not show any noticeable difference on the amount of marginal willingness to pay on CO_2 emission reduction, but other attributes showed that Japanese consumers had much larger willingness to pay than that of Korean Consumers. Park and Jeon (2009) cited that the difference between the Korean and Japanese was that the concept of house purchases in Korea lies in investment rather than residence, which means that

Korean consumers are reluctant to pay additional price for additional functions not related to the residential building's fundamental attribute.

Lee et al. (2012) investigated level of perception toward green buildings on professionals and non-professionals. In the study, awareness of green building was asked through a simple survey without using revealed or stated preference data. Experts and non-experts agreed that green buildings are necessary, and green building themselves are to increase the value of buildings. Experts suggested that the green building certification system in Korea needs to be transformed into an appropriate system for domestic situations by comparing and analyzing both Korea's and international systems. In case of non-experts, they showed high interest in environmental issues, and thus high confidence in green buildings was evaluated from the survey.

Zero Energy Apartment is basically a building that is energy efficient and can produce energy on its own at the same time. Therefore, Zero Energy Apartment should take into account elements for the installation of renewable energy generation facilities in addition to the essential, regional, and eco-friendly attributes. Research on renewable energy has also been steadily carried out as awareness of environmental pollution has risen. Generally, public's acceptance of electricity from renewable energy supply produced by suppliers such as firms has been studied.

Lee. (2015) used Contingent Value Method to analyze public's acceptance on domestic renewable energy. It was found that Korean consumers' willingness to pay on electricity produced from renewable energy was 3,456 KRW per month. By multiplying Korean population, willingness to pay was calculated as 765.5 billion KRW per year, meaning that replacing fossil fuel with renewable energy has value of 887.1 billion KRW per year. Apart from deriving public's acceptance, Lee. (2015) suggested strategies to raise public's acceptance. For raising public's acceptance on renewable energy, the study suggested social element and individual element, noting the importance of socially proving the validity of renewable energy to the public.

In Lee, Bu, and Lee. (2005), 1,467 electricity consumers were surveyed to study the potential demand for green electricity to provide basis for the green electricity premium based on the estimated value of willingness to pay. The average willingness to pay of electricity consumers was estimated to be 1,610 KRW and indicated that to increase public's acceptance of green electricity, promotion of the utility of renewable energy was necessary along with marketing strategies for specific organizations or people with high acceptance level of green electricity are needed at the introduction level.

2.4 Motivation and Goal of this Study

Studies introduced in section 2.3 separately considered attributes of housing choice, and eco-friendly attributes when analyzing consumers' preference. Since Zero Energy Apartment is a new kind of building that is a residential building with eco-friendly attributes and renewable energy facility, its special characteristics should be comprehensively considered as attributes in the housing choice study. Comprehensive analysis of the characteristics will make it possible to figure out attributes of the Zero Energy Apartment that consumers consider the most. It is important to check that consumers' preference on renewable energy facilities as well as eco-friendly attributes are high, meaning that the attributes will be highly considered in housing choice situation. This study is different in that it comprehensively considered the attributes that have been separately considered. This study intends to identify consumers' willingness to pay for Zero Energy Apartments, review the practical feasibility of Zero Energization obligations that is planned to be applied to private buildings in 2025, and present directions for efficient diffusion of Zero Energy Apartment and Zero Energy Building, as well as green buildings.

Chapter 3. Methodology

In this study, Discrete Choice Experiment was processed to consumers to acquire stated preference data. To analyze the data, one of the Discrete Choice Model, Mixed logit model was used.

3.1 Data

Consumers' preference data can be divided into two categories. One is stated preference data and the other is revealed preference data (DA Hensher, 1993). Revealed preference data is defined as the data that shows consumers' preference for products or services such as their purchases and sales in the market at an observable level. On the other hand, products or services that have not yet been traded in the market, such as those that have not been released to the market, or transaction content or sales volume that are unknown are obtained by directly asking consumers using Discrete Choice Experiments and the collected responses are called stated preference data (Kroes & Sheldon. 1988).

In Discrete Choice Experiment, key attributes for the target product, service or project and levels of the key attributes should be determined to be analyzed. Based on the attributes and levels set, hypothetical alternatives that are likely to exist are constituted. The produced alternatives are presented to the respondents, who are the potential consumers in the market, through designed survey, which lead them to choose the most preferred alternative.

In this study, the amount of data available for analyzing consumers' preference on Zero Energy Apartment is insufficient, since the number of buildings with certified grades is very small and there is no active trading in the market as shown in Literature Review. Therefore, consumers' preference on Zero Energy Apartment should be analyzed using the stated preference data obtained from the consumer survey through Discrete Choice Experiment. It is reasonable to use stated preference data in the study since installing renewable energy facility and eco-friendly attributes were not considered in the aforementioned studies, which means that consumers' preference structure is not analyzed.

Again, to design a Discrete Choice Experiment, appropriate attributes and levels of the target product or policy should be set (Gustafsson, Herrmann, and Huber. 1999). In this study, as stated in Literature Review, attributes related to housing choice, attributes related to environment friendly residential buildings, and presence of renewable energy generating facility will be considered comprehensively to analyze Zero Energy Apartment in the housing choice situation.

When setting attributes related to housing choice, it is important to be aware that individual's housing choice is different from each other depending on their purpose of purchase. For example, households with children might consider education as the most important value, and therefore choose a house closest to school with high quality, while unmarried consumers might consider distance to workplace as the most important factor. However, since all the individuals are heterogenetic in housing choice behavior, there are too many attributes to consider, which means it is impossible to consider every single attribute that consumers care about. So it is important to control other attributes suggesting particular conditions. Therefore, before operating Discrete Choice Experiment, this study set certain conditions to control other attributes that not used in the study.

First, regardless of their residential status such as rental or own, respondents were suggested a condition that they were purchasing to move to a new apartment. For example, people living in rental houses were suggested with a situation that they are buying a new apartment to move to. Second, to prevent deviation when moving to completely different district, respondents were suggested with a condition that moving is only allowed in the district they belong to.

The reason apartment is the only residential building type suggested to the respondents is that over 50% of the Korean citizen is researched to be living in apartments at an increasing rate, and the target respondents were people living in big cities, where most of the residents are living in apartments. According to Statistics Korea’s survey of residential conditions report, 2017, it was found that over 50% residents living in metropolitan areas living in apartment with a growing rate. Additionally, it was found that over 80% of the newly constructed residential buildings were apartments which means that the ratio of the apartment in the residential building type will increase over time.

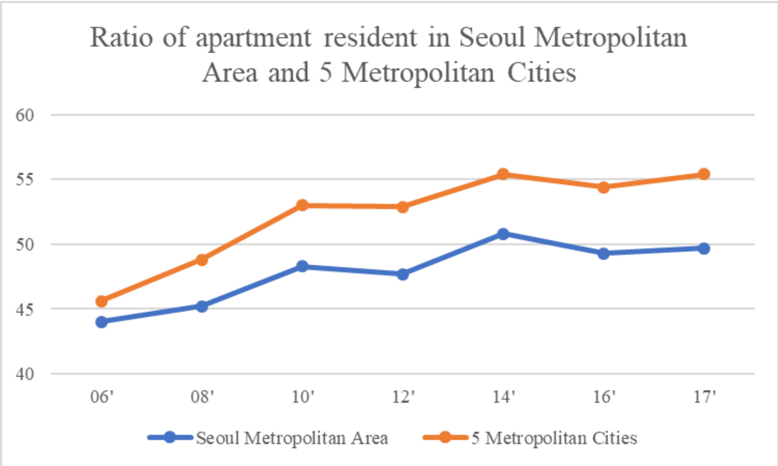

Figure 3. Ratio of Residents Living in Apartment of 5 Metropolitan Cities and Seoul Metropolitan area

3.1.1 Attributes and Levels

Attributes and levels used in the Discrete Choice Experiment are listed in Table 8.

Table 8. Attributes and Levels

Attribute	Attribute description and levels	
1. Brand/Size of the construction firm	description	The size of the construction firm that built Zero Energy Apartment(Brand value proportional to firm size).
	level (2)	1. Large Firm (Raemian, Xi, Ipark, Prugio, etc.) 2. Small and medium size firm (Sclass, .bora, Koaroo, etc.)

2. Accessibility to schools and public transports	description	Walking distance to schools and public transports.
	Level (3)	1. 5minute by walking (Schools and public transports exist in approximately 500M distance) 2. 10minute by walking (Schools and public transports exist in approximately 1KM distance) 3. 15minute by walking (Schools and public transports exist in approximately 1.5KM distance)
3. Whether to install Renewable Energy Generating facility	Description	Whether to install renewable energy generating facility such as geothermal or solar panel for energy produce.
	Level (2)	1. Install 2. Do not install
4. Type of ventilation	Description	Depending on the type of ventilation, the air quality and energy efficiency differs.
	Level (3)	1. natural ventilation by opening doors and windows 2. mechanical ventilation that only help maintain air quality 3. heat recovery ventilation that help maintain air quality and reduce energy use.
5. Reduction of CO_2 emission	Description	Possible amount of CO_2 emission reduction when living in a Zero Energy Apartment.
	Level (3)	1. 1.2tonCO_2 per year in a household 2. 4.8tonCO_2 per year in a household 3. 8.4tonCO_2 per year in a household
6. Energy usage cost saving in percentage	Description	Possible percentage of cost saving of energy use such as lighting, heating, cooling when living in a Zero Energy Apartment.
	Level	1. save 30%

	(3)	2. save 60% 3. save 90%
7. Price increase of Apartment per $3.3m^2$	Description	Price increase per $3.3m^2$ when moving to Zero Energy Apartment compared to the residential building respondents are living.
	Level (3)	1. 1,000,000KRW increase per $3.3m^2$ 2. 2,000,000KRW increase per $3.3m^2$ 3. 3,000,000KRW increase per $3.3m^2$

First attribute is the size and brand of the construction firm that build the Zero Energy Apartment. In case of Korean apartment market, there are notable preferences toward big firm's apartment brands (Shim, 2016). Whether an apartment is built by big firms or small and medium firms matters since price in the apartment market is different. Apartments with big firms' brand names are usually sold more expensively compared to the small and medium firm's brands. Since there are premiums granted to the apartments with higher brand value, consumers tend to prefer big brands with higher marketability. According to LG Economic Research Institute's report, apartment's brand was found to be the most important factor that consumer considers when purchasing an apartment. Table 9 shows the factors researched by LG Economic Research Institute that consumers in Korean apartment market considers the most. According to LG Economics Research Institute, Brand was found to be the most important factor, followed by traffic, investment value, price and possibility of development.

Table 9. Order of Factors Considered by Consumers in Apartment Choice

Factor	Rank
Brand	1
Traffic	2
Investment Value	3
Price	4
Possibility of development	5

<Customer Satisfaction Strategies in Apartment Market, LG Economic Research Institute, 2004>

Second attribute is the accessibility to schools and public transports. Including Louviere, J., & Timmermans, H. (1990) and Yong Tu and Goldfinch. (1996), many studies have considered accessibility of residential buildings as core attributes in consumer's housing choice. Korea Housing Institute also announced that location, which includes the accessibility to education and public transports was the most important factor in consumer's housing choice (Korea Housing Institute, 2011.09.27). In Korean apartment market, consumers tend to prefer apartments with high marketability as apartment purchases are often made for speculative purposes other than for residential purposes based on distance to public transports, schools, etc. Therefore, accessibility to public transports and schools was considered as important determinant of consumer's housing choice, and the level of the attribute was set at 5 minutes, 10 minutes, and 15 minutes by walking distance with approximate distance 500 M, 1 KM, and 1.5 KM.

Third attribute is the presence of renewable energy generator in the apartment complex. To be certified as a Zero Energy Building, the apartment complex should be able to produce energy using renewable energy. In case of Korea, there are no studies progressed dealing with consumer's preference on installing renewable energy generating facility in apartment complex. Furthermore, there are studies about local residents having sense of disapproval about the installation of renewable energy generating facilities near or in their region (Kim, 2005; Byun et al. 2010). Despite the fact that there are local residents' opposition to renewable energy, it is necessary to confirm that research has not been conducted a condition when renewable energy generating facilities can help residents' energy cost saving.

Fourth attribute is the type of ventilation system. High energy efficiency of Zero Energy Building is based on the constancy of temperature. To maintain indoor temperature without changing, energy efficient ventilation as well as insulation and windows with high energy efficiency is important. Natural ventilation, usually done by opening windows, lets the outdoor air directly come into the house which fluctuates indoor temperature, and it cannot guarantee indoor air quality. Along with the natural way of ventilation, mechanical ventilation cannot prevent temperature fluctuation since it only changes indoor air with outdoor air. In case of the heat recovery ventilation, the ventilation system mechanically exchanges the temperature of the outdoor air inflowing with the indoor air exhausted making the temperature remain constant, which is energy efficient (Passive House Institute Korea, 2010). Ventilation system is important in that it alleviates the energy demand of the apartment, making it possible to become a Zero Energy Apartment.

Fifth attribute is the possible amount of reduction in CO_2 emission per year. Reduction of CO_2 was also used in Park and Jeon. (2009). People's interest is increasing on green buildings, meaning that reduction of CO_2 can positively affect consumer's utility. In case of Zero Energy Apartment, high energy efficiency is secured and can produce certain amount of energy through renewable energy which means that there is low demand on energy from fossil fuel. Reducing the demand of fossil fuel produced energy leads to Green House Gas reduction like CO_2. Expected reduction amount was set as 1.2tonCO_2,4.8 tonCO_2, and 8.4 tonCO_2 to investigate consumers' preference on eco-friendly attribute of Zero Energy Apartment. For respondents' better understanding, effect of reduction of CO_2 was suggested as number of trees planted as an example.

Sixth attribute is the possible amount of energy cost that can be saved. When high energy efficiency is gained and renewable energy generation is possible, demand for use of public electricity will drop, resulting in energy cost saving. According to Kim (2015), assuming that all consumers use as much energy as they need each year, the electricity and heating costs are 144,196 KRW per month on a 25pyeong[2] basis. Therefore, on the basis of 30 pyeong, electricity and heating costs can be derived as 173,035 KRW. The purpose is to investigate consumer demand for the attributes of Zero Energy Apartment, which can save 51,900 KRW, 103,800 KRW, and 155,700 KRW, respectively, by setting the level at 30%, 60%, and 90%.

The last attribute is the price increase per pyeong when building a Zero Energy Apartment compared to respondents' present residential building. Price attribute is used to derive marginal willingness to pay of the other attributes used in the study. In case of Zero Energy Apartment, high performance materials are used in the building process, which makes it 30-50% more expensive to build. According to Ministry of Land, Infrastructure, and Transport, at least 30% of construction cost increase is inevitable and can also rise to 50%, which can act as a barrier for Zero Energy Apartments to be built and supplied. However, one thing to look at is that construction firms are reluctant to build Zero Energy Apartments due to high construction cost, which means that consumer's preferences are not considered, leaving possibilities that if consumers are willing to pay for the expensive apartment with several advantages, the construction firms will start building the Zero Energy Apartment, and thus the reason why consumers' demand should be investigated.

---

[2] Pyeong is unit used to measure the area of land. 1 pyeong is approximately 3.3m^2.

3.1.2 Composition of Alternatives

In the design process of Discrete Choice Experiment, alternative set to be given to respondents should be conducted using alternative combination of the previously determined attributes and the levels of the attributes. The number of alternatives that can be created by combining the attributes and levels used in this study is 2·2·3·3·3·3·3, a total of 972 possible alternatives. Since it is practically impossible to use all the 972 alternatives for the respondents to compare, alternative card is made based on the Fractional Practical Design. A total of 32 alternatives were created using statistical program R. Of the 32 alternatives, eight alternatives were excluded from the set since they were clearly superior, or inferior compared to the other alternatives. With the remaining 24 alternatives, three alternatives were combined in a set with one no-choice alternative, creating 8 alternative cards. No-choice alternative induced respondents to make a choice when the utility for Zero Energy Apartments is lower than that of their present residential buildings. During the choice experiment, eight cards mentioned above were divided into two sets, presenting one set to half of the respondents and the other to the remaining half of the respondents. Respondents were asked to respond to the most preferred alternative cards presented in the survey sheet, and those who chose no-choice alternative were asked to rank among the other three alternatives except the no-choice alternative. The survey presented to the respondents is attached in the Appendix.

3.2 Empirical Model

In this study, Discrete Choice Model based on Random Utility Theory was used to analyze the stated preference data obtained from the aforementioned Discrete Choice Experiment. The Discrete Choice Experiment used in this study is consisted of a structure that provides respondents with alternatives that may exist in real market and allows respondents to choose their most preferred alternative among the alternatives suggested. Therefore, it is necessary to analyze discrete choices rather than general regression. This is mainly because the Discrete Choice Model is the most appropriate model for analyzing the reasonable behavior of consumers who choose the alternatives that give respondents the highest benefit among the choices available, similar to the circumstances in which they actually make their choices.

3.2.1 Background

Based on the Random Utility Theory, indirect utility that respondent n is expected to gain from selecting one alternative i within the entire selectable alternative set of C_n, can be expressed as Equation (1) (McFadden, 1973; Train, 2009).

$$U_{ni} = V(s_n, x_{ni}) + \varepsilon_{ni} \cdots\cdots\cdots\cdots \quad (1)$$

In Equation (1), U_{ni} is the utility that respondent n gets from choosing i alternative. As expressed in equation (1), utility of respondent n from choosing alternative i, U_{ni}, can be divided into deterministic utility, V_{ni}, and stochastic utility, ε_{ni}. Deterministic utility, V_{ni}, is the part of the utility that can be captured by the researcher which is considered as observable utility. V_{ni} is affected by individual n's attribute, s_n, and attribute of the alternative i faced by the respondent, x_{ni}.

Each respondent would choose the alternative that maximizes his or her utility among all the alternatives given. It can be expressed as Equation (2).

$$P_{ni} = \Pr\left(U_{ni} > U_{nj}, \forall j \neq i\right) = \Pr(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj}, \forall j \neq i) \quad \cdots\cdots \quad (2)$$

In Equation (2), the probability that respondent n chooses a particular alternative i is equal to the probability that alternative i will have the highest utility than all the other alternatives. It can be expressed as Equation (3) using cumulative probability distribution, $f(\varepsilon_n)$, for random variable *n*.

$$\begin{aligned} P_{ni} &= \Pr(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj}, \forall j \neq i) \\ &= \int_{\varepsilon} I(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj}, \forall j \neq i) f(\varepsilon_n) d\varepsilon_n \end{aligned} \quad \cdots\cdots\cdots \quad (3)$$

In equation (3), I(·) is the indicator function, and various Discrete Choice Models can be applied depending on the assumption of the cumulative probability function of ε_n, $f(\varepsilon_n)$. Different models can be derived also by reflecting the heterogeneity of consumers' preferences. For multinomial logit model, the basic Discrete Choice Model, each stochastic utility, ε_{ni}, is assumed to be independent from each other and identically distributed extreme value distribution. In this case, the probability that respondent *n* chooses alternative *i* among *J* alternatives can be simply expressed as Equation (4) (McFadden, 1974; Train, 2003).

$$\Pr(Y_n = i) = \frac{\exp(V_{ni})}{\sum_{j=1}^{J} \exp(V_{nj})},\ j = 1, ..., J \quad \cdots\cdots\cdots\cdots \quad (4)$$

Multinomial logit model generally has the advantage of having a simple choice probability form derived, making it relatively easier to estimate, but assumes that all consumers have the same coefficient and has unrealistic Independent from Irrelevant Alternatives characteristics, in which the ratio of the choice probabilities of the two alternatives is not affected by changes in the attributes of the unrelated alternatives. This assumptions act as limitation of multinomial logit model. This kind of limitation can be solved by using mixed logit model which reflects individuals' heterogeneity by assuming distributions for the estimated coefficients (Train, 2009).

In mixed logit model, the coefficient vector, β_n , is assumed that the population follows normal distribution with mean *b* and variance *W*. Stochastic utility, ε_{ni} , is assumed to be independent from each other and identically distributed extreme value distribution. Indirect utility when respondent *n* chooses alternative *i* among *J* alternatives from total of *T* choice sets can be expressed as equation (5).

$$U_{nit} = V_{nit}(x_{it}) + \varepsilon_{nit} = \beta_n^{'} x_{nit} + \varepsilon_{nit}, \quad \beta_n \sim N(b,W), \quad t = 1,...,T \quad \cdots\cdots (5)$$

Since ε_{ni} is independent and identically distribute extreme value distribution when β_n is given, the choice probability on respondent *n*'s observed choice appears in the same form with common multinomial logit model.

$$L(y_n \mid \beta_n) = \sum_{t=1}^{T} \frac{\exp(\beta_n^{'} x_{yt})}{\sum_{j=1}^{J} \exp(\beta_n^{'} x_{jt})} \quad \cdots\cdots\cdots\cdots (6)$$

However, β_n are unknown coefficients that also need to be estimated, which makes choice probability of mixed logit model in integral form as expressed in equation (7) (Train, 2003).

$$L(y_n \mid b, W) = \int L(y_n \mid \beta_n)\phi(\beta_n \mid b, W)\, d\beta_n \quad \cdots\cdots\cdots\cdot \ (7)$$

Mixed logit model has the advantage of being able to establish different types of distributions depending on the effect of each attribute on the consumer for each attribute factor. Generally, parameters are assumed to follow normal distribution, but when it is clear the consumer preferences have a particular direction, log-normal distribution is assumed. In particular, for price attribute, it is appropriate to assume log-normal distribution rather than normal distribution to assume negative preferences since it is feasible for all consumers to prefer lower prices over higher prices.

Thus, mixed logit model assumes specific distribution to reflect general preference structure of consumers for each coefficient, it is possible to accurately analyze consumer's preferences. Since the value of the coefficients estimated through the mixed logit model represents a marginal contribution to the utility of each attribute with a random unit, comparison between the attributes have no meaning unlike the general models, and that is why marginal willingness to pay of each attribute is needed. Marginal willingness to pay means the amount that a consumers are willing to pay to keep their utility the same as before when the amount or quality of the attribute changes by one unit. Marginal willingness to pay can be expressed as equation (8).

$$MWTP_{x_{it}} = -\frac{\partial U_{ni} / \partial x_{it}}{\partial U_{ni} / \partial x_{i,price}} = -\frac{\beta_t}{\beta_{price}} \quad \cdots\cdots\cdots\cdots \text{(8)}$$

In equation (8), x_{it} and β_t stands for the attributes except the price and its coefficient, and $x_{i,price}$ and β_{price} stands for the price attribute and its coefficient.

Relative importance, which each attribute affects decision maker’s choice, can be different. Relative importance of each attribute can be derived using part-worth. Part-worth can be derived by Equation (9).

$$part\text{-}worth_{nk} = \text{interval of attribute } k\text{'s level} \times \beta_n \quad \cdots\cdots\cdots\cdots \text{(9)}$$

Part-worth of *k* is derived by multiplying β_k with the difference of minimum and maximum level of attribute *k*.

Relative importance can be derived using equation (10)

$$RI_k = \frac{part-worth_k}{\sum_k part-worth_k} \times 100 \quad \cdots\cdots\cdots\cdots\cdots\cdots \text{(10)}$$

3.2.2 Model Specification

In this study, mixed logit model, a flexible Discrete Choice Model was used to analyze consumers housing choice and consumers' preference when Zero Energy Apartment is available in the market. Maximum Likelihood Estimation was used for the estimation.

Before introducing the empirical model used in the study, variables will be introduced as listed in Table 10.

Table 10. Analyzed Variables

Variable	Definition	Distribution
$D_{i,bigfirm}$	Dummy variable Zero Energy Apartment with big firm brand If big firm brand 1, if small and medium firm brand 2	Normal distribution
$x_{i,access}$	Explanatory variable Accessibility to schools and public transports (1minute walking distance)	Normal distribution
$D_{i,renewable}$	Dummy variable Zero Energy Apartment with renewable energy generator If installed 1, if not 0	Normal distribution
$D_{i,mechvent}$	Dummy variable Zero Energy Apartment with mechanical ventilation system If installed 1, if natural ventilation 0	Normal distribution
$D_{i,heatvent}$	Dummy variable Zero Energy Apartment with heat recovery ventilation system	Normal distribution

	If installed 1, if natural ventilation 0	
$x_{i,CO2}$	Explanatory variable Amount of possible CO_2 reduction per year (1ton per year)	Normal distribution
$x_{i,save}$	Explanatory variable Possible amount of percentage of energy cost save (1% energy cost saving)	Normal distribution
$D_{i,nochoice}$	Dummy variable The choice of not choosing any option	Normal distribution
$x_{i,price}$	Explanatory variable Price increase compared to present residence (1million KRW per pyeong)	Log-normal distribution

Variables $x_{i,access}$, $x_{i,CO2}$, $x_{i,save}$, and $x_{i,price}$ are explanatory variables that are used in the empirical model of this study. Explanatory variable $x_{i,access}$ represents accessibility to schools and public transports. $x_{i,CO2}$ represents the amount of possible CO_2 reduction per year by choosing to live in a Zero Energy Apartment. $x_{i,save}$ represents the possible amount of energy cost save in percentage. Finally, $x_{i,price}$ is set as price variable to derive marginal willingness to pay, meaning price increase per pyeong compared to present residence.

Variables $D_{i,bigfirm}$, $D_{i,renewable}$, $D_{i,mechvent}$, $D_{i,heatvent}$, and $D_{i,nochoice}$ are dummy variables. $D_{i,bigfirm}$ represents whether the Zero Energy Apartment is built by a large firm. When built by large firm, it is presented as 1 and otherwise 0. $D_{i,renewable}$ represents whether renewable energy generator is installed in the apartment complex. When renewable energy generating facilities are installed it becomes 1 and if not, 0. $D_{i,mechvent}$ represents whether mechanical ventilation system is installed. It becomes 1 when installed, and 0 if not installed. Same and $D_{i,mechvent}$, $D_{i,heatvent}$ becomes 1 when heat recovery ventilation system is installed and 0 if not installed. Finally, $D_{i,nochoice}$ represents no-choice where respondent chooses not to prefer Zero Energy Apartment compared to their present residence.

As stated in 3.2.1 that assumptions about distributions of parameters are possible in mixed logit model, distributions were given to each variable. $x_{i,price}$, the price variable, was assumed to follow log-normal distribution and the rest of the attributes were assumed to follow normal distribution.

Using the variables defined, empirical model for analysis will be introduced. In this study, the empirical model is used to check consumers' average preference. Equation (11) is the empirical model used in this study.

$$\begin{aligned} U_{ni} = {} & \beta_{n1}D_{i,bigfirm} + \beta_{n2}x_{i,access} + \beta_{n3}D_{i,renewable} + \beta_{n4}D_{i,mechvent} + \beta_{n5}D_{i,heatvent} \\ & + \beta_{n6}x_{i,CO2} + \beta_{n7}x_{i,save} + \beta_{n8}D_{i,nochoice} + \beta_{n9}x_{i,price} + \varepsilon_{ni} \end{aligned} \quad \cdot\cdot\ (11)$$

Estimating individuals' coefficient, β_n, of each attribute in the mixed model is done by using Maximum Likelihood Estimation method or Bayesian Estimation Method. In this study, Maximum Likelihood Estimation is used for the analysis. According to Train (2003), estimation of maximum likelihood of mixed logit model is processed by the following procedure.

Choice probability of logit when respondent n chooses alternative i is L_{ni}, and choice probability of mixed logit is P_{ni} ,which can be expressed as in equation (12).

$$P_{ni} = \int L_{ni}(\beta) f(\beta \mid \theta) d\beta \text{ and } L_{ni}(\beta_n) = \frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} \quad \cdots\cdots\cdots\cdots \quad (12)$$

Among the density function, $f(\beta \mid \theta)$, a β can be drawn from the distribution which can be marked as β^1. With the β^1 from the distribution, $L_{ni}(\beta^1)$ can be calculated. Then the process of drawing the β is repeated R times, drawing $\beta^1, \beta^2, ..., \beta^r, ..., \beta^R$. With the logit probabilities, $L_{ni}(\beta^1), ..., L_{ni}(\beta^r), ..., L_{ni}(\beta^R)$, calculated with the βs drawn from the distribution, choice probability of mixed logit can be derived following equation (13).

$$\breve{P}_{ni} = \frac{1}{R}\sum_{r=1}^{R} L_{ni}(\beta^r) \quad \cdots\cdots\cdots\cdots\cdots \quad (13)$$

When the simulated mixed logit probability, P_{ni}, is inserted into the log-likelihood function, Simulated log-likelihood can be derived as in equation (14).

$$SLL = \sum_{n=1}^{N}\sum_{j=1}^{J} d_{nj} \ln(\breve{P}_{nj}) \quad \cdots\cdots\cdots\cdots \quad (14)$$

$d_{nj} = 1$ if respondent n chooses j alternative

The maximum simulated likelihood estimator is the θ that maximizes the simulated log-likelihood (Train, 2003).

With the estimated parameter, $\breve{\theta}$, and describing the distribution of β in the population, individuals' β can be derived by following procedure. Let $g(\beta \mid \theta)$ be the distribution of all the β in the population, where θ is the parameter of the distribution, and $h(\beta \mid i, x, \theta)$ be the distribution of β in the subpopulation of people who choose alternative i, when faced with choice situation described by variables x. Thus, $g(\beta \mid \theta)$ is the distribution of β over the whole population, and $h(\beta \mid i, x, \theta)$ is the distribution of β over a subpopulation in the population. Then it is possible to say that $h(\beta \mid y, x, \theta)$ is the distribution of the subpopulation of people who make choice y when facing situations described by variables x (Train, 2003).

Now considering alternatives $j = 1, \ldots, J$ in choice situation $t = 1, \ldots, T$, the utility of respondent n can be expressed as equation (15).

$$U_{njt} = \beta_n' x_{njt} + \varepsilon_{njt},\ \varepsilon_{njt} \sim \text{iid extreme value},\ \beta_n \sim \text{g}(\beta|\theta) \quad \cdots\cdots\cdots\cdots \quad (15)$$

Let $y_n = \langle y_{n1}, ..., y_{nT} \rangle$ be respondent's chosen alternative. Since we don't know β_n, the probability of respondent's choice can be expressed using mixed logit probability as in equation (16).

$$P(y_n \mid x_n, \theta) = \int P(y_n \mid x_n, \beta) g(\beta \mid \theta) d\beta \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (16)$$

With Bayes' rule, $h(\beta \mid y_n, x_n, \theta)$ can be derived by following equation (17).

$$h(\beta \mid y_n, x_n, \theta) \times P(y_n \mid x_n, \theta) = P(y_n \mid x_n, \beta) \times g\left(\beta \mid \theta\right) \quad \cdots\cdots\cdots\cdots \quad (17)$$

$h(\beta \mid y_n, x_n, \theta)$ can be rearranged as equation (18).

$$h(\beta \mid y_n, x_n, \theta) = \frac{P(y_n \mid x_n, \beta) g(\beta \mid \theta)}{P(y_n \mid x_n, \theta)} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (18)$$

Using the distribution of subpopulation, mean of β in the subpopulation can be calculated by equation (19).

$$\bar{\beta}_n = \int \beta \cdot h(\beta \mid y_n, x_n, \theta) d\beta \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (19)$$

Since the integral of the equation (19) is not a closed form, simulated estimate of subpopulation mean can be derived by taking R draws of β from $g(\beta \mid \theta)$, and multiplying them with the weights as in equation (20)

$$\breve{\beta}_n = \sum_r w^r \beta^r \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (20)$$

The weights are calculated as in equation (21).

$$w^r = \frac{P(y_n \mid x_n, \beta^r)}{\sum_r P(y_n \mid x_n, \beta^r)} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (21)$$

With the calculated $\breve{\beta}_n$, marginal willingness to pay of the consumers on each attribute can be derived (Train, 2003).

In this study, consumers' preference will be analyzed using the empirical model described and investigate marginal willingness to pay of consumers on each attribute. Result of the analysis will be specified in chapter 4.

Chapter 4. Empirical Analysis

Result of the empirical analysis using mixed logit model will be discussed in this chapter.

4.1 Descriptive Statistics

Data obtained through discrete choice experiment will be introduced in this section. The survey for data collection was conducted for three weeks from April 1st to 22nd, 2019, covering 701 men and women with age older than 20 and under 60 in eight regions (Seoul, 5 metropolitan cities, Ilsan, and Bundang). The survey was done by a professional survey company Gallup Korea and was conducted via face-to-face survey. The respondents' gender, age, educational background, residential areas, monthly income and marital status are listed in Table 11.

Table 11. Sociodemographic Characteristics of Respondents

	Total	701	100.0 %
Gender	Male	353	50.4 %
	Female	348	49.6 %
Age	20s	163	23.3 %
	30s	167	23.8 %
	40s	183	26.1 %
	50s	188	26.8 %
Residential area	Seoul	286	40.8 %
	New Town	64	9.1 %

	Metropolitan cities	351	50.1 %
Duration of residence	Under 10 years	175	25.0 %
	10-20 years	159	22.7 %
	20-30 years	186	26.5 %
	Over 30 years	181	25.8 %
Family member	Single	78	11.1 %
	2 people	72	10.3 %
	3 people	140	20.0 %
	4 people	352	50.2 %
	Over 5 people	59	8.4 %
Job	Self-employment	174	24.8 %
	Blue collar	220	31.4 %
	White collar	173	24.7 %
	Rest	134	19.1 %
Education level	Under high school graduate	282	40.2 %
	Over college graduate	419	59.8 %
Monthly income	Under 2,000,000KRW	11	1.6 %
	2,000,000~3,000,000KRW	70	10.0 %
	4,000,000~7,000,000KRW	549	78.3 %
	7,000,000~1,000,000KRW	63	9.0 %
	Over 10,000,000KRW	6	0.9 %
	Do not know/no response	2	0.3 %
Monthly expenditure	< 2,000,000KRW	96	13.7 %
	< 3,000,000KRW	223	31.8 %
	< 4,000,000KRW	237	33.8 %
	4,000,000KRW <	145	20.7 %

Briefly looking at the sociodemographic characteristics, 50.4% of the respondents are male and the rest of the respondents are female. Ratio of the respondents’ age seems identical in proportion. 75% of the respondents answered that they have lived in their residence for more than 10 years. 40.8% of the respondents answered that they reside in Seoul, while the rest lives in metropolitan cities and new towns.

Table 12 and 13 shows that over 56% of the respondents are living in apartments presently with average of 29 pyeong in size.

Table 12. Residence Type of Respondents

Type of residence	Number of respondents	percentage
Large complex apartment	238	34.0 %
Small-medium size complex apartment	158	22.6 %
Detached dwelling	290	41.5 %
Office-tel & dormitory	13	1.9 %

Table 13. Respondents’ Size of the Residence

Size of residence	Number of respondents	percentage	average
Under 20 pyeong	64	9.1 %	29 pyeong
< 20 pyeong	574	82.0 %	
< 50 pyeong	48	6.9 %	
Over 50 pyeong	14	2.0 %	

When respondents were asked how much their present residence was being affected by the outdoor air, over 69% of the respondents answered that their present residence was affected by outdoor temperature. Additionally, when respondents were asked with the most important factor for indoor temperature constancy, 16% answered that temperature constancy was achievable by refraining ventilation, 37.9% answered that continuous heating and cooling helps maintain temperature, and 46.1% answered that high performance insulation is needed, which means that almost half of the consumers are aware of the importance of insulation performance of buildings, while the other half is unaware of the power of insulation.

Table 14 shows respondents' perception about environment related questions and Zero Energy Building.

Table 14. Respondents' Awareness of Environmental Problem and Management

	Very low	low	Neutral	High	Very high
Interest in energy & environment	3 (0.4%)	51 (7.3%)	210 (30%)	342 (48.8%)	95 (13.6%)
Degree of environment pollution in Korea	1 (0.1%)	16 (2.3%)	121 (17.3%)	352 (50.2%)	211 (30.1%)
Korean government's coping of environmental problem	14 (2.0%)	177 (25.2%)	289 (41.2%)	196 (28%)	25 (3.6%)
Interest in saving energy	3 (0.4%)	40 (5.7%)	261 (37.2%)	349 (49.8%)	48 (6.8%)
Awareness of Zero Energy Building/House	62 (8.8%)	176 (25.1%)	252 (35.9%)	201 (28.7%)	10 (1.4%)

Respondents were found to have quite high interest in energy and environmental problems. It can be supported from the fact that over 80% of the respondents actually think that environment is highly polluted in Korea. Respondents tend to think that Korean government is coping with environmental problems at a normal level. More than 50% of the respondents showed high interest in saving energy since their interest in energy and pollution seems high and saving energy is directly related to their monthly expenditure. Awareness of Zero Energy Building showed quite similar proportion in the answer asking about Korean government's efforts on coping of environmental problems, which means that government's efforts to address environmental or energy related problems can be an opportunity to raise people's confidence in the government.

4.2 Estimation Result and Analysis

In this study, statistical program Stata was used for the estimation. As mentioned in Chapter 3, Maximum Likelihood Estimation was used for the estimation of the whole population's parameter. Analysis on consumers' preference toward Zero Energy Apartment was carried out and marginal willingness to pay as well as relative importance was estimated using the stated preference data. In the next section, result of the estimation and analysis will be dealt.

4.2.1 Estimation result

Estimation result of the empirical model, Equation (11), using the mixed logit model is shown in Table 15 and Table 16. Stated preference data from the survey was used.

Table 15. Estimated Mean (*b*) of Population's Distribution of β,

Variables	Coefficient	Standard Error	Z	p>|z|
$D_{i,bigfirm}$	1.0419***	0.1766	5.9	0
$x_{i,access}$	-0.1507***	0.0254	-5.93	0
$D_{i,renewable}$	0.2523*	0.1451	1.74	0.082
$D_{i,mechvent}$	0.3170**	0.1498	2.12	0.034
$D_{i,heatvent}$	0.2738	0.3025	0.91	0.365
$x_{i,CO2}$	0.1829***	0.0352	5.2	0
$x_{i,save}$	4.5776***	0.4606	9.94	0
$D_{i,nochoice}$	-1.9656***	0.4037	-4.87	0
$x_{i,price}$	-0.9397***	0.2765	-3.4	0.001

With the estimated result of the parameter of the population's distribution of the coefficients, coefficients of attributes at individual level can be drawn. Estimated result of the median value of each individuals' coefficient is shown in Table 17.

Table 16. Estimated Variance(W) of Population's Distribution of β

Variables	Coefficient	Standard Error	Z	p>|z|
$D_{i,bigfirm}$	1.7989***	0.1965	9.15	0
$x_{i,access}$	0.1885***	0.0358	5.27	0
$D_{i,renewable}$	0.1322	0.1507	0.88	0.38
$D_{i,mechvent}$	-0.4616**	0.1953	-2.36	0.018
$D_{i,heatvent}$	0.3588	0.2700	1.33	0.184
$x_{i,CO2}$	-0.0558*	0.0317	-1.76	0.078
$x_{i,save}$	0.0303	0.5141	0.06	0.953
$D_{i,nochoice}$	-2.5663***	0.2805	-9.15	0
$x_{i,price}$	1.0032***	0.1209	8.3	0

Table 17. Median Value of Individuals' Coefficient (β_n) Estimated

Attributes	Median Value of individuals' coefficients	Assumed distribution
Big firm	0.9409	Normal distribution
Access	-0.1533	Normal distribution
Renewable	0.2404	Normal distribution
Mech vent	0.2284	Normal distribution
Heat vent	0.1928	Normal distribution
CO_2	0.1681	Normal distribution
Cost save	4.4148	Normal distribution
No-choice	-1.9677	Normal distribution
Price	-0.5595	Log-normal distribution

With the estimated median value of individuals' coefficients, marginal willingness to pay of consumers on each attribute can be derived simply by using Equation (8). Relative importance of the attributes also can be derived using Equation (9) and (10). Derived marginal willingness to pay and relative importance of the attributes are listed in Table 18.

Table 18. Estimated Marginal Willingness to Pay and Relative Importance

Attributes	Median of estimated MWTP of each individual	RI(%)
Big firm Apartment	≒ 1,210,000 KRW	9.49%
Accessibility to schools and public transports	≒ -235,000 KRW	12.05%
Renewable energy facility installation	≒ 289,000 KRW	4.32%
Mechanical ventilation system Installation	≒ 258,000 KRW	5.61%
Heat recovery ventilation system installation	≒ 212,000 KRW	9.09%
Amount of possible CO_2 reduction	≒ 223,000 KRW	10.89%
Amount of possible Energy cost saving	≒ 67,000 KRW	19.90%

Estimated marginal willingness to pay of apartment built by big firm is 1,210,000 KRW per pyeong. Consumers tend to have high preference on the brand of big firms. High willingness to pay indicates that there are strong preferences for apartments with large firms' brand. In case of Korean apartment market, demand of apartment with big firms' brand is actually preferred to the small and medium firms' brands, which leads to marketability of the apartment.

Apart from considering marketability as the factor, big firms are known to have more experience in building apartments, and they provide good services to consumers who purchase their apartments, meaning that customer satisfaction is higher than the small and medium size firms.

Marginal willingness to pay when walking minute gets closer by a minute is 235,000KRW/pyeong. As many studies have announced that accessibility of a house positively affects residents, it was found that Korean consumers also prefer apartments close to schools and public transports. It is mainly because Korean apartment market considers access to schools and public transports as a very important factor that could grant price premiums to the apartments.

Marginal willingness to pay on installing ventilation systems were found to be very high. Marginal willingness to pay for installing mechanical ventilation system is 257,000 KRW and 212,000 KRW for installing heat recovery ventilation system. Considering the fact that market price to install ventilation system does not exceed more than 50,000 KRW per pyeong, marginal willingness to pay for ventilation systems are considered very important to the residents. It is probably because air pollution worsened recently in Korea which led consumers to have exceeding preference on ventilation systems.

Marginal willingness to pay for 1ton reduction in CO_2 emission is 223,000 KRW per pyeong. Respondents were found to have positive utility on reducing Greenhouse Gas. From the fact that reduction of CO_2 emission positively affects consumers' utility, it is possible to say that consumers are aware of the climate change, meaning that promotions related to CO_2 reduction can positively affect consumers' utility.

Marginal willingness to pay for installing renewable energy generating facility in apartment complex is 289,000 KRW per pyeong. From existing studies, it was found that people were reluctant to having renewable energy facilities near there residence due to health and scenic problems. This result is meaningful in that consumers' utility can be positively affected when there are direct advantages from installing renewable energy facility such as energy cost saving.

Finally, marginal willingness to pay for saving 1% of energy use cost was found to be 67,000 KRW per pyeong. It is inspiring that people have preferences on reducing energy use that could lead to energy demand reduction. Marginal willingness to pay for energy use reduction was found to be high, since it is directly related to monthly expenses of the consumers. Apart from the expenses consumers can reduce, it is possible to say that consumers have preference on buildings with high energy efficiency, considering the fact that green buildings have better temperature constancy and provide better air quality related to the indoor living environment compared to that of apartments with bad energy efficiency.

With each consumer's coefficient derived using mixed logit model, estimating the probability of choosing Zero Energy Apartment in the real market is possible.

Before estimating the probability in the market, baselines should be set. Three baselines were set to estimate the probability.

First, baseline for Zero Energy Apartment was set. To set the baseline for a particular Zero Energy Apartment, a case in Songdo, Korea was used. As of 2018, there is only one apartment over 7 stories that is under construction, which is expected to be certified as Zero Energy Building. It is expected to be certified as grade 5, having 22% energy independence capable of reducing about 40% of the energy use compared to existing apartments. Second, baseline for apartment with high energy efficiency was set. Based on the data from Ministry of Land, Infrastructure and Transport, it was found that the average energy efficiency level of the apartments recently certified was about half the Zero Energy Apartment, meaning that they are capable of reducing about 20% energy use. Apartments with high energy efficiency usually installs heat recovery ventilation systems and insulation products with high performance. Third, baseline for normal apartment with no reduction of energy use or CO_2 emission was set. The two types of apartment, which is Zero Energy Apartment and energy efficient apartment is different in that Zero Energy Apartment has much higher energy efficiency and it can reduce additional energy use with renewable energy generating facility. The Zero Energy Apartment can be understood as an upgrade version of energy efficient apartment with renewable energy generator.

With the three types of apartments and its baselines, choice probability can be derived by using empirical model. Table 19 shows the baselines set for each type of apartment and the choice probability.

From the derived choice probability for three types of apartments, it was found that over half of the consumers are willing to choose Zero Energy Apartment. It is inspiring that once Zero Energy Apartment is introduced in the market, it will overtake more than half of the apartment market even with high price. The result that a Zero Energy Apartment with additional price of 3,000,000KRW per pyeong showed the highest probability is important in that the consumers have big preference on the Zero Energy Apartment even when considering the high price. It is possible to say that Zero Energy Apartment will be favored by the customers.

Table 19. Choice Probability and Baselines Set for 3 Type of Apartments.

	Zero Energy Apartment	Apartment with Energy efficiency grade 1	Apartment with no reduction
Renewable energy Facility	Installed	Not installed	Not installed
Heat recovery ventilation	Installed	Installed	Not installed
Reduction of CO_2	1.92 tonCO_2	0.96 tonCO_2	0 tonCO_2
Reduction of energy use	40 %	20 %	0 %

Price	Additional 3,000,000KRW increase per pyeong	Additional 1,000,000KRW increase per pyeong	No additional price
Choice Probability	51 %	6 %	43 %

Since the choice probability of the Zero Energy Apartment with Zero Energy level 5 was high, it is important to derive the willingness to pay for Zero Energy Apartment. By deriving the willingness to pay for Zero Energy Apartment, it will be possible to suggest feasible range of construction expense increase for Zero Energy Apartments to be diffused.

It is possible to include Heat recovery ventilation into the choice probability situation even though the parameter for the population was derived to be insignificant. The coefficient used in the choice probability situation was derived from the individual level and the attribute which was derived not to have significance in the population level can be considered important when deriving individual level coefficient (Train, 2009).

Willingness to pay for Zero Energy Apartment can be done using the marginal willingness to pay of each attribute. Before deriving the willingness to pay for Zero Energy Apartment, baseline should be set. In this study, baseline for Zero Energy Apartment was set according to a case in Songdo, Korea. The Zero Energy Apartment under construction in Songdo is expected to have 22% energy independence with 40% energy use reduction capability, 40% CO_2 reduction capability, installing renewable energy facility and heat recovery ventilation system. Other attributes should be fixed to use marginal willingness to pay of each attribute. Therefore, the willingness to pay for Zero Energy Apartment with Zero Energy grade 5 on the base of normal apartments without reduction capabilities and Songdo case, can be calculated using Equation (22).

$$\begin{aligned} WTP_{\text{ZeroEnergyApartment5}} &= MWTP_{\text{renewable}} + MWTP_{\text{heatvent}} \\ &+ MWTP_{\text{CO2}} \times (CO_2 \text{ reduction}) \\ &+ MWTP_{\text{costsave}} \times (\text{possible reduction amount}) \end{aligned} \quad \cdots\cdot (22)$$

Calculated willingness to pay for Zero Energy Apartment with Zero Energy level 5 is approximately 3,600,000 KRW per pyeong. 3,600,000 KRW per pyeong can explain respondents' choice probability on Zero Energy Apartment. The set increasing price for Zero Energy grade 5 Zero Energy Apartment was 3,000,000 KRW per pyeong which means that it was set lower compared to consumers' willingness to pay. From the result, it is possible to say that this study suggested consumers' willingness to pay to address concerns about consumer demand for construction firms' Zero Energy Apartment. If Zero Energy Apartments can be constructed within the scope of the willingness to pay of the consumers presented in this study, consumers will prefer Zero Energy Apartments to existing ones. The high willingness to pay for Zero Energy Apartment can be considered in a way that the product has additional psychological values apart from the advantages that consumers can gain. The increase in consumers' utility living in a Zero Energy Apartment can be understood by considering that the individuality that Zero Energy Apartment has can represent consumers' individuality and satisfy consumers' desire for differentiation.

Chapter 5. Conclusion

Control of energy demand and reduction of Greenhouse Gas emissions are global challenges. Earth's temperature is constantly rising due to excessive Greenhouse Gas emissions. When global efforts are needed, most countries, including Korea, are implementing policies in various ways to protect the planet from global warming and environmental destruction. Korea is one of the highest CO_2 emitting countries all over the world, and the energy demand is much higher than the amount of energy resources. In order to resolve energy security problem and participate in the movement to protect earth's environment, Korean government have announced strategy to diffuse New Energy Industry. Through New Energy Industry, Korean government aimed at achieving economic growth and economic activation as well as energy demand and Greenhouse Gas reduction.

Zero Energy Building is one of the government-led New Energy Industries. Zero Energy Buildings have much higher energy efficiency compared to existing buildings, and at the same time, they can solve their own energy demand by using renewable energy generation facilities. This study focuses on the particular type of building, apartment that occupy the most energy demand in Korean buildings and investigate consumers' preference on Zero Energy Apartments for efficient diffusion.

Diffusion of Zero Energy Buildings in Korea is very slow. In particular, the number of residential buildings is very small. This is a problem to be looked at in terms of the supply of construction firms, rather than consumer demand. Consumers' acceptance on Zero Energy Apartments should be suggested to alleviate construction firms' concerns on consumers' demand to promote the supply of Zero Energy Apartments. Analyzed consumers' preference on Zero Energy Apartment can be referenced to construction firms' cause of concern, which will lead to supply of Zero Energy Apartment that reduces energy demand and CO_2 emission. Thus, this study aims to contribute to alleviating energy demand and CO_2 emission problems and revitalizing domestic construction economy.

Stated preference data was obtained through Discrete Choice Experiment on 701 respondents. Mixed logit model was used to analyze preference of respondents. For the Discrete Choice Experiment, core attributes of Zero Energy Apartment in housing choice situation was defined to investigate the effect of each attributes of Zero Energy Apartment on consumers' housing choice. Total of 7 attributes were defined and 24 alternatives were conducted.

The result showed that people had high acceptance on Zero Energy Apartment. It was found that installing ventilation system and renewable energy facility positively affected consumers' utility. Also, it was found that people had high preference on reducing CO_2 and energy demand. Choice probability of Zero Energy Apartment at Zero Energy grade 5 was found to be preferred than the existing apartments even with a high increase in the apartment's price.

Marginal willingness to pay for each attribute were derived and utilized to derive willingness to pay for Zero Energy Apartment with Zero Energy grade 5. It was found that consumers were willing to pay additional 3,600,000 KRW per pyeong, which means that consumers think highly of Zero Energy Apartment. It is important that willingness to pay for Zero Energy Apartment was derived since consumers' willingness to pay can be used as a reference to construction firms concerned about consumers' demand with high price Zero Energy Apartment. If it is possible to supply Zero Energy Apartments within the willingness to pay of consumers, it can be justified to supply from the viewpoint of the construction firms since Zero Energy Apartments are preferred by the consumers compared to existing apartments.

This study can suggest various implications according to the result of the analysis. First, people were found to have interest in environment friendly buildings. If residential buildings can be supplied within consumers' willingness to pay, diffusion of Zero Energy Buildings as well as green buildings will be feasible in the actual market. Second, since consumers' preference on Zero Energy Building is high, government's plan to make all the newly built buildings to become Zero Energy Building is reasonable for the consumers. Third, renewable energy facility, which is often rejected by the residents due to health and scenery problems will positively affect their utility if direct advantages can be suggested.

Fourth, Zero Energy Apartment has the potential to be granted with price premium in the market, which means that it will be favored by the consumers due to high marketability. Fifth, from the fact that choice probability of Zero Energy Apartment was relatively high compared to that of apartment with good energy efficiency, it is possible to say that the consumers want Zero Energy Apartment with better energy efficiency which means that supplying Zero Energy Apartment instead of supplying apartments with good energy efficiency is better in increasing consumers' utility. Finally, the willingness to pay for ventilation system was found to be higher than the market price, meaning that promoting the use of ventilation systems with high performance can be an efficient way to quickly improve energy efficiency as well as indoor living environment.

Jeong & Shin, (2002), analyzed apartment residents' housing choice factors through Analytic Hierarchy Process. 7 factors (economic factor, location factor, indoor space factor, complex facility factor, complex factor, indoor facility factor, and indoor comfort factor) were chosen as the housing choice factor. It was found that economic factor was mostly considered by the residents when choosing their apartment. The 7 factors were divided into 55 specific factors, and public transportation, surrounding environment, access to school, energy use cost, investment value, environment friendliness, etc. were found to be considered the most while the price of the apartment was the 53th considered specific factor. From the result of the Analytic Hierarchy Process, it is possible to say that due to t considerably high price of apartment in Korea, the consumers in the apartment market tend to be insensitive to the price of the apartment. Instead, the consumers are sensitive to the factors that are related to the potential price increase.

Considering the fact that consumers' preference is high toward Zero Energy Apartment, complex factor and indoor comfort factor can be considered as the economic factor. It is because the eco-friendliness and discriminative characteristics of Zero Energy Apartment can be considered as an additional value to the consumers. From the fact that Zero Energy Apartments have many characteristics that Korean consumers would prefer, it is important to emphasize the advantages that Zero Energy Apartment have which can increase consumers' preference rather than focusing on the methods to lower the burden of consumers due to high price of the Zero Energy Apartment.

Bibliography

Savaresi Annalisa. (2016). “The Paris Agreement: a new beginning?”. Journal of Energy & Natural Resources Law. 34(1). 16-26

Banfi, S., Farsi, M., Filippini, M., & Jakob, M. (2008). “Willingness To Pay For Energy-Saving Measures In Residential Buildings”. Energy Economics. 30(2). 503-516.

Byun. S. -Y, Jeong. M. -H., Park. J. -C., and Lee. U. -G., (2010). "A Study on the Importance Evaluation of Renewable Energy Complex Application". Journal of Architectural Institute of Korea. 26(6). 333-340. [Korean]

Choi. D. -Y., (2015). "Permanent Sampling Research on Building Energy Consumption (Second Year)". Korea Energy Economics Institute. [Korean]

Choi. D. -Y., (2016). "Permanent Sampling Research on Building Energy Consumption (Third Year)". Korea Energy Economics Institute. [Korean]

Lee. C. -Y., (2015). "A Study on the Improvement of Public Acceptance on Renewable Energy". Korean Energy Economics Institute. [Korean]

Jeong. G. -H. and Shin. N. -S., (2002). "A Study on the Priority of Residential Choice by the Apartment Resident". Journal of Architectural Institute of Korea. 18(1). 21-28

Lee. G. -D., Bu. K. -J., and Lee. C. -H., (2005). "Methods to revitalize Renewable Energy Electricity Market". Korean Energy Economic Institute. [Korean]

Global Green Growth Institute. (2015). “Korea’s green growth experience”.

Gustafsson, A., Herrmann, A., Huber, F. (2000) Conjoint Measurement: Methods and Applications, Springer-Verlag Berlin Heidelberg.

DA Hensher and M, Bradley. (1993). “Using stated response choice data to enrich revealed preference discrete choice models”. Marketing Letters. 4(2). 139-151.

Hu, H., Geertman, S., & Hooimeijer, P. (2014). “The Willingness To Pay For Green Apartments: The Case Of Nanjing, China”. Urban Studies. Forthcoming.

Shim. H. -S., (2016). "Choosing the appropriate apartment: 33 methods not to be fooled by apartment". Korean Economic Daily. [Korean]

Lee J. -H., Choi. H. -W., Yang. Y. -K., Lee. K. -K., and Park. J. -C., (2012). "Analysis of Consumer Needs Survey for Promotion of Green Building". Proceedings of Korean Society for Promotion of environment friendly facilities. 61-64. [Korean]

Kim. H. -Y., (2015). "A Study on the Effect of Energy Efficiency Rating System on Housing Choice". Master’s thesis., Seoul National University

Korea Energy Agency. (n.d.). “What is Zero Energy Building?”. Retrieved from https://zeb.energy.or.kr/introduceZero/introduce.aspx

Korea Institute of Civil Engineering and Building Technology. (2017). "A Study on System Improvement and Supporting System for Activation of Zero Energy Building”. [Korean]

Korea Ministry of Land, Infrastructure and Transport. (n.d.). “Zero Energy

Building Activation". Retrieved from http://www.molit.go.kr/USR/WPGE0201/m_36421/DTL.jsp.

Korea Research Institute of Eco-Environmental Architecture. (n.d.). "Zero Energy Building Certification System". Retrieved from http://www.kriea.re.kr/home/s3/s3_2_1.php.

Korean Housing Institute. (2011). "Analysis of housing purchase decision factors". [Korean]

Korean Ministry of Environment. (2018). "GHG Emission in 2016 exceeded 694.1 million ton, increased 0.2% to last year". [Korean]

Kroes, E., & Sheldon, R. (1988). Stated Preference Methods: An Introduction. Journal of Transport Economics and Policy, 22(1), 11-25.

Kwak, S.-Y., Yoo, S.-H., & Kwak, S.-J. (2010). "Valuing Energy-Saving Measures In Residential Buildings: A Choice Experiment Study". Energy Policy, 38(1), 673-677.

LG Economy Research Institute. (2004). "Customer Satisfaction Strategies in Korean's Apartment Market". [Korean]

Louviere, J., & Timmermans, H. (1990). Hierarchical Information Integration Applied To Residential Choice Behavior. Geographical Analysis, 22(2), 127-144.

Lee. M and Park S. -K. (2017). "Assessment of Korea's GHG Reduction Targets Through Comparative Analysis of OECD Countries' Nationally Determined

Contributions (NDCs)". Journal of Climate Change Research. 8(4). 313-327. [Korean]

M.Gluszak, 2015 Multinomial logit model of housing demand in Poland. Real Estate management and valuation. 23(1) 84-89

Macpherson, D. A., & G, S. S. (1999). Forecasting seniors housing demand in Florida". Journal of Real Estate Portfolio Management, 5(3), 259-274.

Park. M. -S., and Jeon. J. -Y. (2009). "Comparative Study on Consumer Preferences for Apartment's Environment Performance". Journal of Architectural Institute of Korea. 25(3). 255-262. [Korean]

Molin, E., Oppewal, H., & Timmermans, H. (1996). Predicting Consumer Response To New Housing: A Stated Choice Experiment. Netherlands Journal Of Housing And The Built Environment, 11(3). 297-311.

Nairobi. (2014). "The Emissions Gap Report 2014". United Nations Environment Programme (UNEP).

Passive House Institute Korea. (2019.05.19) "Understanding Heat Recovery Ventilation System". Retrieved from http://www.phiko.kr/bbs/board.php?bo_table=z3_01&wr_id=14.

Torcellini, Pless and Deru. (2006). National Renewable Energy Laboratory. Conference Paper.

Train, K. (2003). "Discrete Choice Methods With Simulation, 1st Ed." Cambridge University Press. 105-142.

Train, K. (2009). Discrete Choice Methods with Simulation, 2nd Edition. New York. Cambridge University Press. 105-142.

Trenberth, K E, Jones, P D, Ambenje, P, Bojariu, R, Easterling, D, Klein Tank, A, Parker, D, Rahimzadeh, F, Renwick, J A, Rusticucci, M, Soden, B, & Zhai, P. Observations. Surface and Atmospheric Climate Change. Chapter 3. United Kingdom.

U.S. Energy Information Administration. (2014). “Country Analysis Brief: South Korea”

Kim. Y. -S., (2017). "Status of Zero Energy Buildings and Improvement Tasks". National Assembly Legislation Bureau. [Korean]

Yong Tu and Judy Goldfinch. (1996). “A Two-stage Housing choice Forecasting Model.” Urban Studies. 33(3). 517-537

Kim. Y. -J., (2005). "Establishment of Renewable Energy Evaluation System". Korean Renewable Energy Society Conference Proceedings. 656-659. [Korean]

Appendix 1. Survey

Survey was conducted to analyze consumers' preference on Zero Energy Apartment. 701 respondents were questioned to obtain stated preference data. Survey was operated by Gallup Korea, a professional research institute. Total of 24 alternatives were derived through Discrete Choice Experiment design. 8 cards were created with the 24 alternatives. 4 cards with no-choice alternative was given to half of the respondents and the other 4 cards were suggested to the other half. Every questions accept the alternative cards were commonly suggested to respondents. Specific Survey information is included in Appendix 1.

70 SAJIKRO JONGRO-GU SEOUL, KOREA, 03167 TEL(02)3702-2100 / FAX(02)3702-2121/E-mail info @gallup.co.kr / internetwww.gallup.co.kr
affiliated with ***GALLUPINTERNATIONAL***

GMR2019-141-008 **첨단 기술 제품에 대한 인식 조사** (TYPE X-Y)

			X	Y

안녕하십니까? 저는 시장조사 전문기관인 한국갤럽조사연구소 면접원 ○○○입니다.

한국갤럽조사연구소에서는 서울대학교 산학협력단의 의뢰로 일반국민 여러분의 첨단 기술 제품에 대한 인식을 알아보고 있습니다. 본 질문에는 맞고 틀리는 답이 없으며, 이런 의견을 갖고 있는 사람이 몇 퍼센트 (%)라는 식으로 통계를 내는 데에만 사용되며, 그 외의 목적에는 절대로 사용되지 않으니 평소 생각대로 응답해 주시면 됩니다. 또한, 귀하께서 응답해 주신 내용은 통계법(제33조)에 따라 통계목적으로만 사용되며, 귀하의 의견은 철저히 보호됨을 약속드립니다. 바쁘시겠지만, 조사에 협조해 주시면 대단히 감사드리겠습니다.

2019년 4월
한국갤럽조사연구소
박재형

실사 담당 : 정슬기 대리 (02-3702-2689)

먼저, 응답자 선정 질문입니다.

SQ1. 성 : 1. 남자 2. 여자

SQ2. 실례지만, 귀하의 올해 만 나이(=2019-출생년도)는 어떻게 되십니까?

만 [|] 세 ─▶ **만20~59세 사이만 조사 진행**

SQ3. 지역 :

1. 서울 2. 신도시(경기도 일산) 3. 신도시(경기도 분당)
4. 인천 5. 부산 6. 대구
7. 광주 8. 대전

SQ4. 귀하께서 현재 살고 계신 지역에 거주하신지는 얼마나 되셨습니까?

[|] 년 [|] 개월 째 거주 중

SQ5. 현재 귀하와 함께 살고 있는 가족은 모두 몇 명입니까? 응답자 본인을 포함한 가족 수를 응답해 주십시오.

나를 포함해, 같이 살고 있는 가족은 모두 [|] 명임.

SQ6. 귀하께서는 자녀가 있으신지요? 만약 있으시다면, 10세 이하의 자녀가 몇 명 있으십니까?

1. 없다 2. 1명 3. 2명 4. 3명 5. 4명 이상

다음 페이지부터 응답자 자기기입식으로 응답해 주십시오.

질문 응답 시 유의사항

1. 질문지는 순서대로 응답해 주십시오. 특별한 언급이 없다면, 모든 질문에 빠짐없이 응답해 주시기 바랍니다.
2. 질문에 응답하시기 전에 질문 앞에 제시된 설명문을 잘 읽고, 숙지하신 후 응답해 주시기 바랍니다.
3. 질문에 대한 응답은 제시된 보기번호에 ○표 해 주시면 되며, 질문 항목별로 특별한 언급이 없는 한 가장 최근을 기준으로 응답해 주시면 됩니다.

- 1 -

문6. 귀하께서 현재 살고 계신 **주택의 면적**은 어떻게 됩니까? 공급면적으로 응답해 주십시오.

※ 평수 또는 m^2 중, 귀하께서 알고 계시는 단위 하나에만 응답해 주시면 됩니다. **(1평은 약 3.3**m^2 **입니다.)**

[| |] 평 또는 [| |] m^2

문7. 귀하께서 현재 살고 계신 **집이 외부 온도에 어느 정도 영향**을 받는다고 생각하십니까?

전혀 영향받지 않는다	영향받지 않는 편이다	보통이다	영향받는 편이다	매우 영향 받는다
1	2	3	4	5

문8. 귀하께서는 **하루 시간을 주로 어떻게** 보내십니까? **평일**과 **휴일**로 나누어 응답 **시간의 합**이 **24시간**이 **되도록 응답**해 주십시오.

1) 평일(월요일~금요일) 24시간 응답란

통근 (출근+퇴근시간)	집에서 생활	여가 시간 (취미 활동)	수면	일과시간 (직장 등에서 보내는 시간 등)	기타	합계
약 [|] 시간 +	약 [|] 시간 +	약 [|] 시간 +	약 [|] 시간 +	약 [|] 시간 +	약 [|] 시간 =	24시간

2) 휴일(토요일~일요일 및 공휴일) 24시간 응답란

통근 (출근+퇴근시간)	집에서 생활	여가 시간 (취미 활동)	수면	일과시간 (직장 등에서 보내는 시간 등)	기타	합계
약 [|] 시간 +	약 [|] 시간 +	약 [|] 시간 +	약 [|] 시간 +	약 [|] 시간 +	약 [|] 시간 =	24시간

문9. 귀하께서는 1년 중 **전기료**와 **난방비**가 가장 많이 나오는 달에 얼마를 지불하십니까?

1) **전기료** 약 [|] 만 [ ] 천원

2) **난방비** 약 [|] 만 [ ] 천원

H-1. 제로에너지아파트에 대한 선호도

먼저, 제로에너지아파트 및 거주 형태에 대한 질문입니다.

문1. 다음 **귀하의 평소 환경에 대한 태도**에 대해 귀하와 가장 가까운 번호에 ○표해 주십시오.

	전혀 그렇지 않다	그렇지 않는 편이다	보통이다	그런 편이다	매우 그렇다
	1	2	3	4	5
1. 나는 **환경 문제**에 관심이 많다 ········	1	2	3	4	5
2. 나는 평소 **에너지/환경 문제**에 관심이 많다 ········	1	2	3	4	5
3. 나는 **세계적인 환경 이슈**에 대해 잘 알고 있다 ········	1	2	3	4	5
4. 나는 평소 **에너지/환경 정책**에 대해 잘 알고 있다 ········	1	2	3	4	5
5. 나는 **친환경 제품**을 구매하는 것을 좋아한다 ········	1	2	3	4	5
6. 나는 **환경오염으로 생태계가 파괴되는 것을 부정적으로 생각**한다 ···	1	2	3	4	5
7. 나는 우리나라 **환경오염이 심각**하다고 생각한다 ········	1	2	3	4	5
8. 나는 우리나라가 **에너지/환경 문제에 잘 대처**하고 있다고 생각한다	1	2	3	4	5
9. 나는 평소 **에너지 절약을 신경쓰는** 편이다 ········	1	2	3	4	5
10. 나는 **제로에너지아파트에 대해 들어보았거나 알고** 있다 ········	1	2	3	4	5

문2. 귀하께서는 **집의 온도를 일정하게 유지하기 위해서 가장 중요한 요소**는 무엇이라고 생각하십니까?

1. **지속적인 냉방(여름철) 및 난방(겨울철)**을 통하여 집 안의 온도를 일정하게 유지한다
2. **우수한 단열재 및 창호를 설치**하여 집 안의 온도를 유지한다
3. 춥거나 더운 공기가 들어오지 못하도록 가급적 **환기를 자제**한다

문3. 귀하께서는 다음 중 **어떤 유형의 주택**에 살고 계십니까?

1. 단독주택 (빌라, 원룸 등)　　2. 오피스텔　　3. 대단지 아파트
4. 중소단지 아파트　　5. 기타

문4. 귀하께서 살고 계신 **주택의 보유 형태**는 다음 중 어디에 해당됩니까?

1. 자가 또는 전세　　2. 월세 또는 기숙사 등 기타 ─▶ **문6.으로 가십시오.**

문5. **(문4.에서 1. 자가 또는 전세를 응답한 경우만 응답해 주십시오.)**
귀하께서 **현재 살고 계신 주택**의...
- (자기인 경우) **매매 가격**(세금을 제외한 현재 혹은 구입 당시의 실 구매가격)과 **구입한 시기**
- (전세인 경우) **전세 가격**과 **이주 시기**를 응답해 주십시오.

1) 매매 가격 또는 전세 가격

1. 1억 이하　　2. 1억~3억 이하
3. 3억~5억 이하　　4. 5억~10억 이하
5. 10억 이상

2) 구입 또는 전세 이주시기

☐☐☐☐ 년 ☐☐ 월

H-2. 제로에너지아파트 유형별 선호도

1. 지금부터는 **제로에너지아파트가 전국적으로 확대**되었을 때, **귀하의 선호도**를 묻는 질문입니다.
2. 응답하실 유형별 선호도 질문은
   ① **주거 유형 설명문** (주거 선택 시 고려해야할 여러 속성과 속성별 수준에 대한 설명)과
   ② **제로에너지아파트 유형별 선호 순위를 묻는 질문**과 **가장 선호하는 유형 질문**이 제시됩니다.

먼저 **주거 유형별 속성 및 수준 설명문**을 숙지한 후, 다음 페이지 질문에 응답해 주십시오.

▣ 주거 유형별 속성 및 수준 설명문

속성		속성 설명 및 수준
1. 시공 건설사의 크기/종류	설명	제로에너지아파트를 **시공한 건설사의 크기**를 의미합니다.
	수준 (2개)	① 대형 건설사 (레미안, 자이, 아이파크, 롯데캐슬, 프루지오, 더샾 등) ② 중소형 건설사 (코아루, 사랑으로, 어울림, 반도유보라 등)
2. 대중교통 및 학교와의 접근성	설명	**대중교통과 학교로부터의 도보거리**를 뜻합니다.
	수준 (3개)	① 도보로 5분 (약 500m 내에 학교와 대중교통이 존재함) ② 도보로 10분 (약 1km 내에 학교와 대중교통이 존재함) ③ 도보로 15분 (약 1.5km 내에 학교와 대중교통이 존재함)
3. 신재생에너지 발전설비 설치여부	설명	아파트 단지 전체에 **지열 및 태양광 발전설비를 설치**할 수 있습니다.
	수준 (2개)	① 설치한다 ② 설치하지 않는다
4. 환기 방법	설명	실내 공기를 쾌적하게 유지하기 위해서는 환기가 필수적입니다. **환기를 하는 방법**에는 자연 환기, 일반 기계식 환기, 열교환식 환기가 있습니다.
	수준 (3개)	① 자연 환기 (창문 개폐를 통한 환기입니다) ② 일반 기계식환기 (일반적인 환기 시스템으로, 창문의 개폐가 없이 밖의 공기를 안으로 들여오고 내부의 공기를 밖으로 배출합니다) ③ 열교환식 환기 (일반 기계식 환기와 비교하여 집 내부의 온도를 일정하게 유지하는데 유리합니다)
5. 연간 감축 가능한 이산화탄소의 양	설명	제로에너지건축물로 인증을 받은 아파트에 거주하는 경우, 친환경 아파트로써 **화석연료의 사용으로 인한 이산화탄소의 배출량을 크게 감소**시킬 수 있습니다.
	수준 (3개)	① 가구당 이산화탄소 배출량 연간 1.2톤 감축 (1년에 30살 소나무 약 200그루 심는 것과 같은 효과) ② 가구당 이산화탄소 배출량 연간 4.8톤 감축 (1년에 30살 소나무 약 770그루 심는 것과 같은 효과) ③ 가구당 이산화탄소 배출량 연간 8.4톤 감축 (1년에 30살 소나무 약 1,350그루 심는 것과 같은 효과)
6. 절약 가능한 전기료 및 난방비용	설명	제로에너지건축물로 인증을 받은 아파트에 거주하는 경우, **전기세와 난방비용을 절약**할 수 있습니다. (30평 기준, 전기료 및 난방비용은 월 평균 173,000원입니다.)
	수준 (3개)	① 30% 절약 (30평 기준, 30% 절약할 시, **월 평균 51,900원 절약 가능**) ② 60% 절약 (30평 기준, 60% 절약할 시, **월 평균 103,800원 절약 가능**) ③ 90% 절약 (30평 기준, 90% 절약할 시, **월 평균 155,700원 절약 가능**)
7. 집의 평당 가격 증가 정도	설명	현재 거주하고 있는 집의 **평당 가격 대비 증가하는 정도**입니다.
	수준 (3개)	① 평당 100만원 증가 (30평 기준, 집의 가격 약 3,000만원 증가) ② 평당 200만원 증가 (30평 기준, 집의 가격 약 6,000만원 증가) ③ 평당 300만원 증가 (30평 기준, 집의 가격 약 9,000만원 증가)

지금부터 앞에서 설명해드린 주거 선택 관련 속성을 조합하여 구성한 **가상의 주거 유형 3개와 기존과 동일한 주거 유형을 동시에 제시한 질문 4개**가 제시됩니다. 귀하께서는 각 질문별로,

① 선호하는 순서대로 **유형의 순위를 1위부터 3위까지** 응답해 주시고,

② 기존과 동일한 주거 유형이 포함된 4개의 주거 유형 중, **가장 선호하는 유형 하나에 O표**해 주시면 됩니다.

※ 귀하께서 현재 살고 있는 주택과 동일한 행정구역 내에서 주거를 이전하고자 하며, 아래 **제시된 속성 이외의 다른 모든 조건들은 동일**하다는 가정 하에 응답해주십시오. (예시: 세종시 30평 개인주택에 거주하는 가구는 동일한 행정구역인 세종시 내에 있는 30평 아파트를 구매하여 이사함)

※ 현재 전세/월세 등 임대나 자가 주택 여부와 관계없이, **같은 지역 내 비슷한 크기의 아파트**를 구매하여 이사를 간다는 가정 하에 응답해 주십시오. (예시: 40평 월/전세 공동주택에 거주하는 가구는 40평 아파트를 구매하여 이사함)

구분		유형 A	유형 B	유형 C	유형 D
질문 1	1. 시공 건설사의 크기	대형건설사 시공	중소형건설사 시공	중소형건설사 시공	추가비용을 부담하지 않고 기존에 살던 집과 비슷한 집을 선택한다
	2. 학교/교통수단 접근성	도보 10분거리 (1km)	도보 5분거리 (500m)	도보 15분거리 (1.5km)	
	3. 신재생에너지 발전설비	발전설비 설치	발전설비 미설치	발전설비 미설치	
	4. 환기 방법	자연환기	일반 기계식환기	자연환기	
	5. 이산화탄소 연간 감축량	연 1.2t 감축	연 1.2t 감축	연 4.8t 감축	
	6. 전기세/난방비 절약	60% 절약가능	30% 절약가능	90% 절약가능	
	7. 집의 평당 가격 상승	300만원 상승	200만원 상승	200만원 상승	
1위~3위까지 선호 순위 응답란 →		☐ 위	☐ 위	☐ 위	
가장 선호하는 유형 응답란 → (4개 유형 중, 하나에 O표)		유형 A	유형 B	유형 C	유형 D

구분		유형 A	유형 B	유형 C	유형 D
질문 2	1. 시공 건설사의 크기	대형건설사 시공	중소형건설사 시공	중소형건설사 시공	추가비용을 부담하지 않고 기존에 살던 집과 비슷한 집을 선택한다
	2. 학교/교통수단 접근성	도보 10분거리 (1km)	도보 5분거리 (500m)	도보 15분거리 (1.5km)	
	3. 신재생에너지 발전설비	발전설비 미설치	발전설비 미설치	발전설비 설치	
	4. 환기 방법	열교환식 환기	자연환기	자연환기	
	5. 이산화탄소 연간 감축량	연 1.2t 감축	연 4.8t 감축	연 8.4t 감축	
	6. 전기세/난방비 절약	30% 절약가능	60% 절약가능	30% 절약가능	
	7. 집의 평당 가격 상승	300만원 상승	300만원 상승	200만원 상승	
1위~3위까지 선호 순위 응답란 →		☐ 위	☐ 위	☐ 위	
가장 선호하는 유형 응답란 → (4개 유형 중, 하나에 O표)		유형 A	유형 B	유형 C	유형 D

구분		유형 A	유형 B	유형 C	유형 D
질문 3	1. 시공 건설사의 크기	대형건설사 시공	중소형건설사 시공	중소형건설사 시공	추가비용을 부담하지 않고 기존에 살던 집과 비슷한 집을 선택한다
	2. 학교/교통수단 접근성	도보 5분거리 (500m)	도보 15분거리 (1.5km)	도보 15분거리 (1.5km)	
	3. 신재생에너지 발전설비	발전설비 설치	발전설비 설치	발전설비 미설치	
	4. 환기 방법	지연환기	열교환식 환기	일반 기계식환기	
	5. 이산화탄소 연간 감축량	연 4.8t 감축	연 8.4t 감축	연 4.8t 감축	
	6. 전기세/난방비 절약	30% 절약가능	30% 절약가능	60% 절약가능	
	7. 집의 평당 가격 상승	300만원 상승	300만원 상승	100만원 상승	
1위~3위까지 선호 순위 응답란 →		☐ 위	☐ 위	☐ 위	
가장 선호하는 유형 응답란 → (4개 유형 중, 하나에 O표)		유형 A	유형 B	유형 C	유형 D

구분		유형 A	유형 B	유형 C	유형 D
질문 4	1. 시공 건설사의 크기	대형건설사 시공	중소형건설사 시공	중소형건설사 시공	추가비용을 부담하지 않고 기존에 살던 집과 비슷한 집을 선택한다
	2. 학교/교통수단 접근성	도보 10분거리 (1km)	도보 10분거리 (1km)	도보 5분거리 (500m)	
	3. 신재생에너지 발전설비	발전설비 설치	발전설비 미설치	발전설비 설치	
	4. 환기 방법	자연환기	일반 기계식환기	자연환기	
	5. 이산화탄소 연간 감축량	연 4.8t 감축	연 8.4t 감축	연 4.8t 감축	
	6. 전기세/난방비 절약	90% 절약가능	60% 절약가능	30% 절약가능	
	7. 집의 평당 가격 상승	300만원 상승	200만원 상승	100만원 상승	
1위~3위까지 선호 순위 응답란 →		위	위	위	
가장 선호하는 유형 응답란 → (4개 유형 중, 하나에 ○표)		유형 A	유형 B	유형 C	유형 D

문5. 다음은 귀하께서 위의 선호도 질문에 응답하면서 비교한 **각 속성별 고려 수준**에 대한 질문입니다.
위 질문에 응답하면서 귀하께서 각 속성에 대해 고려한 수준을 **5점 척도로 응답**하여 주시기 바랍니다.

	전혀 고려하지 않았다.	고려하지 않은 편이다.	보통이다	대체로 고려했다.	매우 고려했다.
	1	2	3	4	5
1. 시공 건설사의 크기	1	2	3	4	5
2. 학교/교통수단 접근성	1	2	3	4	5
3. 신재생에너지 발전설비	1	2	3	4	5
4. 환기 방법	1	2	3	4	5
5. 이산화탄소 연간 감축량	1	2	3	4	5
6. 전기세/난방비 절약	1	2	3	4	5
7. 집의 평당 가격 상승	1	2	3	4	5

문6. 귀하께서 지금까지 응답하신 제로에너지아파트 유형에 대해 **제로에너지아파트의 각 속성별로 귀하께서 기대하는 수준 (특정 수준을 만족하지 않을 경우 선택하지 않는 수준)**을 응답해 주십시오.

제로에너지아파트 속성	기대하는 제로에너지아파트 수준 응답란
1. 시공 건설사의 크기/종류 (1. 또는 2. 중 하나 응답)	1. 대형 건설사 (레미안, 자이, 아이파크, 롯데캐슬, 프루지오, 더샵 등) 2. 중소형 건설사 (코아루, 사랑으로, 어울림, 반도유보라 등)
2. 대중교통 및 학교와의 접근성 (시간 응답)	도보로 최대 ☐☐ 분 이내
3. 신재생에너지 발전설비 설치여부 (1. 또는 2. 중 하나 응답)	1. 설치한다 2. 설치하지 않는다
4. 환기 방법 (1., 2. 또는 3. 중 하나 응답)	1. 자연 환기 (창문 개폐를 통한 환기) 2. 일반 기계식 (창문의 개폐 없이 밖의 안과 밖의 공기를 순환시킴) 3. 열교환식 (일반 기계식 보다 집 내부의 온도를 일정하게 유지하는데 유리)
5. 연간 감축 가능한 이산화탄소의 양 (그루 응답)	가구당 1년에 30살 소나무 ☐☐☐ **그루 이상** 심는 효과
6. 절약 가능한 전기료 및 난방비용 (비율 응답)	현재 대비 최소 ☐☐ **% 이상** 절약
7. 집의 평당 가격 증가 정도 (금액 응답)	평당 ☐☐☐ **만원 이하** 증가

I. 자료 분류용 질문

마지막으로 응답자 분류를 위한 질문입니다.

I1. 귀하의 **직업**은 어떻게 됩니까?

1. 자영업 (종업원 9명이하 소규모업소 주인/가족종사자)
2. 판매/서비스직 (상점점원, 세일즈맨 등)
3. 기능/숙련공 (운전사, 선반/목공, 숙련공 등)
4. 일반작업직 (토목 현장작업/청소/수위/육체노동 등)
5. 사무/기술직 (일반회사 사무직/기술직, 교사 등)
6. 경영/관리직 (5급 이상 공무원/기업체 부장 이상 등)
7. 전문/자유직 (대학교수/의사/변호사/예술가/종교가 등)
8. 전업주부
9. 학생
10. 무직
11. 기타 (구체적으로 응답해 주십시오 : ________________)

I2. 귀하의 **최종학력**은 어떻게 됩니까?

1. 중/고등학교 졸업
2. 전문대 졸업
3. 대학교 졸업
4. 대학원 졸업

I3. 현재 귀 댁의 **월 평균 소득 수준**은 얼마나 됩니까? 세금은 제외한 **보너스, 이자수입** 등 모든 **수입**을 합해서 응답해 주십시오.

1. 99만원 이하
2. 100만원~149만원 이하
3. 150만원~199만원 이하
4. 200만원~249만원 이하
5. 250만원~299만원 이하
6. 300만원~399만원 이하
7. 400만원~499만원 이하
8. 500만원~699만원 이하
9. 700만원~999만원 이하
10. 1,000만원 이상

I4. 그럼, 현재 귀 댁의 **월 평균 소비 지출**은 얼마나 됩니까?

☐ 천 ☐ 백 ☐ 십 ☐ 만원 정도

I5. **[개인정보 수집, 이용 동의] 응답 확인 등 검증에 필요한 개인정보 수집 동의에 대해 여쭙겠습니다.**
① 개인정보의 수집·이용 목적 : 응답자 확인, 응답 확인, 답례제공 여부 확인 등 검증을 위한 개인정보 수집·이용
② 수집하려는 개인정보의 항목 : 응답자 성명, 응답자 연락처
③ 개인정보의 보유 및 이용기간 : 검증 후 6개월
위 개인정보 수집에 동의하십니까? 동의를 거부할 권리가 있습니다.

1. 동의함
2. 동의 안함

★ 끝까지 응답해 주셔서 대단히 감사합니다 ★

면 접 후 기 록			
응답자 성명		응답자 연락처	
조 사 일 시	____월 ____일	면접원 성명	(ID: _______)
실사 검증원	(ID: _______)	실사 연구원	(ID: _______)

Abstract (Korean)

전 세계적으로 에너지 수요 절감과 이산화탄소와 같은 온실가스 배출 감축을 함으로써 기후변화를 완화하려는 노력이 이어지고 있다. 한국의 경우, 예상되는 이산화탄소 배출량의 37% 수준을 목표를 달성하기 위한 정책들 중에서 잠재적으로 경제활성화를 일으킬 수 있는 정책들을 사업 모델화한 에너지 신산업을 발표했다. 제로에너지건축물은 에너지 신산업의 사업 모델 중 하나로, 신재생에너지 발전설비를 설치한 에너지 효율이 매우 높은 건축물이다. 정부의 기대와는 다르게 제로에너지건축물의 확산은 매우 더디게 이루어지고 있으며, 그 수가 매우 적다. 또한, 건축물 중 가장 많은 에너지 소비가 이루어지고 있는 아파트의 경우, 시장에 공급이 극히 적다. 본 연구에서는, 많은 에너지 소비가 이루어지고 있는 아파트의 제로에너지화를 다루고자 하며, 제로에너지아파트에 대한 선호를 분석하고자 한다. 제로에너지아파트에 대한 소비자의 선호연구는 한국에서 아직 이루어지지 않았기 때문에, 아파트를 공급해야 하는 건설사는 수요가 불분명한 제로에너지아파트의 공급에 대한 결정을 할 수 있는 근거가 부족할 것이다. 본 연구는, 이산선택실험을 통해 701명의 제로에너지아파트의 속성에 대한 진술선호자료를 얻었고, 이산선택모형 중 혼합로짓모형을 이용하여 701명의 응답자의 제로에너지아파트에 대한 평균적인 선호를 분석했다. 결과적으로, 응답자들은 제로에너지아파트에 대한 높은 선호를 보이는 것으로 나타났고, 친환경과 관련된 속성들을 선호하는 것으로 나타났다. 본 연구의 결과로부터,

향후 정부가 목표로 하고 있는 2025년 민간 건축물에 대한 제로에너지 의무화의 현실적인 가능성과 타당성을 확인할 수 있었으며, 건설사에게 제로에너지아파트를 공급할 수 있는 근거를 제시할 수 있었다.

주요어 : 제로에너지아파트, 친환경 건축물, 이산선택실험, 혼합로짓모형, 소비자 선호분석
학 번 : 2017-20128